ANNALS

OF THE

NEW YORK ACADEMY OF SCIENCES

VOLUME XLII

NEW YORK
PUBLISHED BY THE ACADEMY
1941–1942

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ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
VOLUME XLII, ART. 1. PAGES 1–112
AUGUST 11, 1941

A SURVEY OF THE LITERATURE ON ARTISTIC BEHAVIOR IN THE ABNORMAL: II. APPROACHES AND INTERRELATIONSHIPS*

BY

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CONTENTS

* This survey is part of a project on the artistic behavior of the insane, conducted by the writers under the auspices of the Columbia University Council for Research in the Social Sciences. The data obtained by the writers in their own investigations have not been included in the present literature survey, but will be reported in subsequent publications.

Publication made possible through a grant from the income of the Esther Herrman Fund, and the John Strong Newberry Fund.

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INTRODUCTION

The artistic behavior of the abnormal has been regarded from such divergent viewpoints and has been related to such a multiplicity of other artistic phenomena that it is difficult to classify and synthesize the material in any definitive manner. The present article is concerned with the basic approaches to the problem of insane art, with the relation of such a problem to the fields of primitive, child, "populistic," and modern and fantastic art, and with special consideration of the questions of genius and insanity in art and the relationship between artistic ability and personality traits. This article represents the second in a series of literature surveys covering different aspects of the major field of artistic behavior in the abnormal. The first article of the series (Anastasi and Foley 1941a) deals with historical and theoretical background, the material being classified geographically and chronologically; the third article (Anastasi and Foley 1940b) is devoted to a survey of the literature dealing with spontaneous productions of the insane; the fourth article (Anastasi and Foley 1941b) surveys the purely experimental investigations; further articles are concerned with the literature on special related phenomena, such as "trance" or mediumistic drawings and prison art. These articles, although autonomous, should logically be considered together and in sequence. It should be constantly kept in mind, as indicated in the other papers, that the term "artistic behavior" is here used to denote the patient's concrete behavior in the activities of drawing, painting, modeling, writing, composing or playing, without recourse to value judgments of any sort whatever.

MAJOR APPROACHES

The Artistic Approach

In the present section we are concerned with the artistic productions of the abnormal from a purely aesthetic point of view, *i. e.*, as art products *per se*. We are interested in the artist's attitude toward insane art, and are not primarily concerned with the relationship between insane productions and modern art, or with the opinion of psychiatrists and neurologists on modern art. Art products by abnormal patients have frequently served as a source of inspiration for various artists, and the techniques used by certain patients,—such as novel media, abstraction, distortion, or adaptation of the grain of wood or other natural phenomena,—have been employed by many

artists. It has been pointed out that such products often display original, "interesting," and striking aesthetic effects. The references in the present section are intended to illustrate the reactions to abnormal products on the part of artists, art critics, and the public at large. Perhaps the best indication of the interest in abnormal products is to be found in the number and popularity of exhibits of such work from a purely artistic point of view. Such products, to be sure, have been exhibited from time to time by psychiatrists for purely medical purposes; this type of exhibit, however, does not concern us here, and will be treated elsewhere by the writers (Anastasi and Foley 1940b).

In its 1936 exhibit of "fantastic art, dada, and surrealism," the Museum of Modern Art in New York City included a small number of insane productions. In the catalogue and handbook to the exhibit, Barr (1936: 182, 186) reproduces a watercolor, a drawing, and a construction from the psychopathic works in the exhibit. A popular discussion of the exhibition is given by Davidson (1936), and a somewhat facetious account is found in an anonymous article in The Art Digest (Anonymous 1936). In 1935, part of the well-known Szecsi collection, containing 45 art productions by the insane, was exhibited at the Midtown Galleries, New York City. The collection was selected from those of Prinzhorn and of Marie and from the asylums of Ville-juif and Sainte Anne in France. In the catalogue of the exhibit, Szecsi (1935) points out that the insane artist is not conscious of creating art, but is led by intense emotional necessity to express the objects of his peculiar "inner world." Szecsi adds that the resulting work "is bound to be beautiful, for immediate creation of a great emotion results in beauty."

An anonymous article (Anonymous 1913) in Current Opinion contains an account of an exhibition of insane art held in London. Comments printed about the exhibit, one from the British Medical Journal, are also cited. Special consideration is given to a discussion of the subject matter and legends on the pictures. The author points out the possible gain for the insane artist in being freed from the necessity of pleasing the public, and concludes regarding the artistic nature of the pictures that "every one worthy of consideration from the artistic point of view betrays the practical hand, and does not suggest the spontaneous evolution of an art expressive of untrammeled ideas."

The curious water-colors, pastels, crayon and black-and-white sketches made by Nijinsky, the famous Russian ballet dancer who

soon after the World War was taken to private sanitaria in Kreuzlingen and Zurich, Switzerland, as a schizophrenic patient, have attracted considerable artistic interest. For a number of years, he was under the care of Dr. Manfred Sakel, then of Vienna, and is said to have undergone insulin therapy. It is reported (Anonymous 1932, Stuart 1938) that M. Paul Claudel, the distinguished French diplomat and friend of Nijinsky, first suggested that art materials be placed at the patient's disposal. The resulting pictures were geometric and bizarre, showing faces and portraits made out of black-and-white or multicolored rhythmically overlapping and intersecting circles and arcs. The works attracted the attention of Freud and Jung, of Vienna, who advised Madame Nijinsky to exhibit them. A collection of more than 50 paintings and drawings, illustrating the progressive stages of the dancer's insanity, were exhibited in New York in 1932 (*cf.* Anonymous 1940a). A similar collection of Nijinsky's works was exhibited under the auspices of the Group Theater at the Storran Gallery in London in 1937 (*cf.* Anonymous 1937, Stuart 1938) in order to raise funds for the sanitarium treatment. An Associated Press dispatch (Anonymous 1937) quotes an official of the Group Theater as stating that although they were shown "as works of art and not as psychological documents," Nijinsky's paintings and drawings are of profound interest "precisely because, being psychological documents, they are at the same time works of art." Numerous illustrations are reproduced in the above-mentioned articles (Anonymous 1932, 1937, 1940a; Stuart 1938), as well as in the books published by Nijinsky's wife (Nijinsky 1934, 1936).

In 1921, an exhibition of insane art was held in Frankfort, Germany, under the auspices of the Department of Psychiatry of Heidelberg University. An American account of the exhibition (Anonymous 1921a) refers to Prinzhorn's lecture on this exhibition, reported in the Frankfurter Zeitung, in which Prinzhorn affirmed that the paintings owed their merit to the fact that their creators were dementia praecox patients. In 1928, an exhibit of painting and sculpture by psychotics was held at the Vanin Gallery in Paris, the works being taken from the well-known collection of Marie. Only the work of patients who were not artists before institutionalization was included in the exhibition. An article in Science (Anonymous 1928) reviews the reports on the exhibit from the French correspondent of the American Medical Association. Several unusual paintings are described, such as a picture of roaring flames and fire, bought by a manufacturer to serve as the basis of a new wallpaper design, and a painting by a psycho-

pathic priest depicting a pope blowing soap bubbles before an assemblage of swooning frogs. Marie, it is reported, was of the opinion that some of the paintings, if removed from their environment and placed in the collections of a reputable dealer, would command high prices.

Another exhibition of works by the insane was held from May 31 to June 15, 1929 in Paris, at the Gallery of M. Bine, 48 Avenue d'Ièna, the proceeds going to the patients who had been discharged as cured. Marie (1929) described this exhibition in the Revue Scientifique, and a popular American account appeared in the Literary Digest (Anonymous 1929). Approximately 200 items were displayed, reminiscent of the collections at Heidelberg assembled by Prinzhorn, who sent some of his most curious specimens to this exhibit. Most of the products were from the collection of Mme. the Marquise de Ludre, who collected with Marie at Ville-juif for several years; other works came from private collections, notably from the pupils of Professors Claude, Laignel-Lavastine, and Bogenoff; Drs. Sérieux, Marchand, Vinchon, and Borel, of Paris; Dr. Pailhas, of Albi; Drs. Mac-Auliffe, Bordet, Rogues de Fursac, of Ville-juif; Dr. Livet and M. Montyel, of Ville-Evrard. Visitors were plentiful, and the exhibition drew enthusiastic comments in the current Parisian press (*cf.* Anonymous 1929). In discussing the exhibit and its implications, Marie (1929) refers to the exhibits of insane art organized by the psychiatric divisions of International Congresses, such as that at Bethlem in London "several years" prior to 1929, at Berlin in 1913, and at Moscow in 1914.

An exhibit on "Art and psychopathology" (Anonymous 1938a, b, c, d, e) was held in October and November, 1938 at the Harlem Community Art Center, New York City, under the joint sponsorship of the Psychiatric Division of Bellevue Hospital and the Federal Art Project, N. Y. C. The material consisted of work by patients in the hospital observation wards and in classes conducted by the Art Teaching Division of the Federal Art Project under psychiatric supervision. The material, consisting of drawings and paintings by children, adolescents, and adults, was selected and captioned for the exhibition by Bender. The catalogue (Anonymous 1938a) lists 106 works, classified according to the age and syndrome of the patient. Various case-types are presented, and sequence-development is illustrated in specific cases. A series of three conferences accompanied the exhibit, with well-known artists, art teachers and critics, and psychiatrists as speakers. The first conference, on October 24, 1938, marked the formal opening of the exhibit, and was concerned with general problems relating to

the field; Drs. K. Bowman and P. Schilder presented the psychiatric point of view; Messrs. H. Cahill and A. R. Stavenitz, the artistic. The second forum, on October 31, 1938, for psychologists, psychiatrists, and psychoanalysts, was addressed by Drs. N. D. C. Lewis, S. Keiser, F. J. Curran, and P. Schilder. The speakers at the third conference, for artists, art critics, and art teachers, on November 7, 1938, included Dr. P. Schilder and Messrs. L. Garfinkle, L. Rothschild, and A. R. Stavenitz. The exhibit and forums were well attended, and occasioned considerable comment in the newspapers (*cf.*, *e. g.*, Anonymous 1938d), as well as in Life (Anonymous 1938b, c) and Time (Anonymous 1938e).

Stavenitz (1939) points out the various advantages of the collaborative work at Bellevue. He discusses its implications (*a*) for the educator, by furthering an understanding of personality differences, especially of the abnormal child; (*b*) for the art critic, in contributing toward an understanding of what the artist is trying to do and why he is doing it; and (*c*) for the practicing artist. Garfinkle (1939) also discusses the art work at Bellevue from the artist's point of view. He holds that many of the pictures, aside from their psychiatric value, have attracted the attention of serious artists, and adds that this is especially true in the case of the schizophrenic patient, who "invariably paints in symbols." Garfinkle discusses what he considers to be the major characteristics of the art products of the common clinical types.

Prinzhorn (Prinzhorn *et al.* 1925) states that the meaning and value of a work of art cannot be judged by a psychopathological yardstick, *i. e.*, the artistic value of the product should be considered independently of the normality or abnormality of the artist. Stertz (1927) agrees with Prinzhorn that schizophrenia does not create artistic values, although he contends that in some cases it may release talent which has found no opportunity of expression in former life.

The enthusiastic reception of insane products into the realm of "legitimate art" has not been without dissenting opinion, however, as is illustrated by the views of Hyslop (1911, 1924, 1927), Pfeifer (1923), Stadelman (1927), and Ruckstull (1925), who deplore what they term the current tendency to elevate insane art. In his famous article on "Post-illusionism and art in the insane," Hyslop (1911) launches a vitriolic attack upon the "post-illusionist" artists and critics whom he regards as either hysteric and neurasthenic "borderland dwellers" or "mattoids," or malingerers. Hyslop's treatment is based upon his observations of the artistic work of patients in

various hospitals; his discussion is often vague and figurative, and shows a strong bias against many of the tendencies in modern art. A popular article in Current Literature (Anonymous 1911) also protests against the insane factors in modern art, with extensive quotations from Hyslop. Distortion in insane art is attributed to illusions and faulty perception. Hyslop reproduces his 1911 article in his later books, "The borderland" (1924: chapt. 13, Health and disease in art) and "Mental handicaps in art" (1927: chapt. 4, Disease in art). In both books, he warns against the "simulation of disease" by imitating visual defects or restricting art to the "grosser emotions."

Pfeifer (1923) maintains that whatever seems artistic in insane drawing is the last remnant of sanity. Stadelman (1927) holds that insane drawing is dissociated, and consequently cannot be regarded as "art." In the appendix to his book, Ruckstull (1925: 497–516) reprints Hyslop's original article and goes on to discuss the similarity of modern and insane art, all of which he characterizes as grotesque, devoid of artistic merit, and distinctly pathological. Reference is made to the work of Pfeifer and of Stadelman as well as to several newspaper articles maintaining the decadent and degenerative character of modern and insane art, Ruckstull contending that the similarity of the two is a sign of the decadence of modern art. This general point of view is reflected in the recent "sanity in art" movement founded by Josephine Hancock Logan, Chicago art patron, in 1936 (*cf.*, *e. g.*, Anonymous 1940b). This society maintains that modern art is degenerate, insane, and not based on "sound fundamental principles." A storm of controversy has greeted the pronouncements and exhibits of the various branches of this society in Chicago, Los Angeles, and various other large cities.

The Psychiatric Approach: Diagnostic Value

It should be pointed out at the outset that most of the contributions discussed in the other articles of the present series have been concerned, directly or indirectly, with the relationship between form of psychosis and characteristics of the drawing or other artistic product. In so far as such a relationship can be empirically shown to exist, to that extent could such characteristics be employed as valid diagnostic indicators of the particular syndrome. The present survey, however, will be limited to articles which have been specially written on this problem or to those in which the author specifically points out the diagnostic value of such productions. It should also be pointed out that no attempt will be made to survey the literature

dealing with the diagnostic use of various drawing scales in the case of neurotic, psychotic, or feebleminded children and adults. All such studies with the Goodenough and other drawing scales as well as with drawings from the Standford-Binet scale and other test series, will be discussed by the writers in a subsequent survey on experimental investigations (Anastasi and Foley 1941b).

The first to suggest the diagnostic value of various art forms produced by psychotic patients was Max Simon (1876), who as early as 1876 pointed out specific characteristics of the *drawings* in the various psychoses. Simon does not confine himself to drawings alone, but discusses other products as well, pointing out, for example, that the individual forms of mental aberration are also distinguishable by the kind of dress, which he discusses in detail. In a later article (1888), he again calls attention to the diagnostic value of both drawings and writings, and attempts to formulate 5 major types, each correlated with a particular syndrome. Régis (1884) concludes that such drawings throw a great deal of light upon the development of manic-depressive psychosis and its change from one phase to another. He states that they are equally valuable in any other form of mania or melancholy, and believes that they may yield definite basis for prognosis.

In volume 2 of his Manual (1885–1894: 551–558), Morselli discusses "individualism" and "ideographism and symbolism" as being the major characteristics of insane art, and reproduces 2 examples from his own collection: a self-portrait by a religious paranoiac, and a symbolic wood sculpture by a paranoiac with political and persecutory delusions. Morselli considers such characteristics to be of considerable diagnostic importance. Although concerned also with the artistic merit of insane productions, Réja (1907), likewise mentions their diagnostic function. Rogues de Fursac (1905) points out that the artistic products of the abnormal are not all of equal clinical value, but can be divided into two classes: (1) those which are directly dependent upon the patient's mental condition, *e. g.*, a paranoid's drawing of an hallucination, and (2) those created merely as an artistic product, *e. g.*, a paranoid's drawing of a landscape.

Mohr's experimental approach to insane drawings (1906–1907, 1908–1909, 1925), to be discussed elsewhere by the writers (Anastasi and Foley 1941b), yielded results confirming those of Simon for spontaneous drawings. Mohr (1906–1907) concludes that the various syndromes have specific expressive reactions; hence drawing reactions, among others, may be indicative of different pathological conditions.

He elsewhere (Mohr 1925: 338) states that such drawings serve as "an indication of inner happenings." In his textbook on "Experimental psychology and pedagogy," first published in 1909, Schulze (1912) refers to the work of Mohr in discussing the use of drawings as an aid to diagnosis with children and with the insane, and reproduces 6 insane drawings from Mohr's publications. Kürbitz (1912), following the techniques of Mohr, also concludes that the drawings of the insane show a close relationship to their disease and that they have a definite diagnostic value. He maintains that for complete diagnosis, drawings should be included: they are necessary but not sufficient for such purposes. Kürbitz adds that spontaneous drawings are much more indicative than those executed under more artificial and limited conditions.

Sapas (1918), using methods similar to certain of those outlined by Mohr in which the subject is required to copy a geometric figure 10″ after exposure, reports characteristics of the reproductions which could be used to differentiate the various psychoses. Sapas reports, "the drawings reflect very lucidly the personality and the characteristics of the disease," and, "therefore scientific and diagnostic value can be attributed to these reproductions." Becker (1934), also influenced by Mohr and his followers, exposed simple designs to 75 schizophrenics and later asked them to reproduce the designs from memory. Various characteristics of the schizophrenic reproductions, such as "expressive patterning," "influence of felt forms," "lack of coordinated plan," etc., were found to differentiate them from the reproductions of a group of 41 normal control subjects. The recent work of a number of investigators on the relationship between syndrome and drawing behavior offers indirect diagnostic implications.

Many other 20th century psychiatrists have directly affirmed their belief in the diagnostic value of insane drawings. Dantas (1900) pointed out that the value of insane art is purely psychiatric. Näcke (1913) holds that only in the acute stages of an attack can signs be found which are of diagnostic value. Aschaffenburg (1915) confines himself almost entirely to the psychiatro-diagnostic use of such products. Häberlin (1916) maintains that when we judge an art product as "imperfect," we are making a similar judgment regarding the artist's personality, since the work of art is only a symbol of the deeper psychological "reality." Pérez (1917) considers both drawings and writings of the insane to be of great diagnostic importance because of their objectivity and their permanence, and maintains that the initiated can detect the type of insanity from picture and writing

as easily as the art critic can classify a picture into the proper school. In his discussion of the drawings characteristic of each clinical type, Pérez goes so far as to contend that all drawings by the same type look as though made by the same person, even though they may come from far distant places and times!

A more conservative and somewhat skeptical view is held by Fay (1912), who does not believe that there is much to learn from an examination of the work of artists who have become insane. He points out that good paintings of delusions and hallucinations are rare; good artists rarely wish to paint such subjects. Fay states that the only examples with which he is familiar are so naïvely executed as to give a poorer idea of the patient's condition than his verbal description. The memory error must also be taken into consideration. Fay adds, however, that it is easier to detect pathological characteristics in the work of the trained artist than in that of the unskilled, whose imperfections of form and technique are difficult to interpret.

As a result of his series of experiments on the creative activities of the insane, Abramov (1910–1911) concludes, "the experimental method employed in this study made it possible to draw lines between the different types of abnormality." Hamilton (1918: 492) states that the use of drawings as indices of the kind of mental disorder is especially justified in the case of paranoia; he cites the case of one of his Bloomingdale patients, suffering from religious delusions, who shaved his head, wore a monk's robe, and drew marvelous mystic pictures, such as "weird heads of divine personages . . . intertwined with leaves and flowers and framed in fantastic arabesques." Hickson (1913–1915) refers to abnormal drawings as "mental finger prints," and cites briefly the diagnostic results obtained in the psychopathic laboratory of the Municipal Court of Chicago with the "Designs from Memory" test of the Stanford-Binet.

Prinzhorn's literature survey (1919) credits Simon with having originated and emphasized the diagnostic approach to insane art. In a later article (1922), Prinzhorn attempts to answer the question, "Are there characteristic schizophrenic forms in the artistic work of the insane?" He describes a series of pictures from the Heidelberg collection, bringing out their characteristics in short captions, but states that he is unable to give a conclusive, diagnostic, and usable answer to the above enquiry. In his book, Prinzhorn (1923a) also devotes considerable space to a discussion of the relationship between the types of insanity and the character of the artistic output, and reiterates the many difficulties of the problem. The con-

servative motif is again dominant in the abstract of a report at a psychiatric meeting, Prinzhorn (1923b) concluding that there is no clear-cut formula for diagnosing the artist's mental state from a drawing. Rather must the drawing be evaluated as one manifestation of the whole personality. Vinchon (1926) states that in a few rare cases, artistic production of a given work may be a precursor of insanity. The case of a young sculptress who, following the death of her lover, turned to religious mysticism and automatic sculpturing, is cited as an example.

Delgado (1922) states that the drawings of the insane, together with their spontaneous or responsive explanations, often allow deep insight into the mental condition and psychopathic disposition of the patient. Delgado also sees in such drawings rich material for the psychoanalyst, and reproduces selected examples of drawings showing "sexual symbols," "overcompensated homosexuality," "intrauterine regression," "incest desires," "sexual bond to a parent," etc. Pfister, who has abstracted the article (*cf.* Delgado 1922), points out that such examples are rare and do not prove the predominance of sexual motives and conflicts in such psychoses. Kempf's psychoanalytic approach to insane drawings (Kempf 1920) implies their diagnostic value. He assumes a fixed "language of symbols" which when "interpreted" reveal a highly sexual "latent content." Many other psychoanalysts have voiced similar, if more conservative, opinions.

Schilder (1918) also considers insane drawings to be rich in symbolic content. In a paper read before the American Psychopathological Association in Philadelphia in 1924, Lewis (1925) lists hypnosis, crystal gazing, automatic writing, dreams, and unconscious mistakes in speech, writing, and other forms of expression as various methods which have been proposed to explore "unconscious dynamic mechanisms." He then discusses in detail (pp. 316–317) "the utilization of the unconscious revelations through graphic art which the patient can be encouraged to produce," and adds that this has long been used as a psychoanalytic technique. Three interpretative levels are outlined: the manifest content, latent content, and deductive or derivative meaning. Lewis elsewhere (1928) discusses the graphic art productions in schizophrenia, affirming that an analysis of such works will "bring to consciousness the underlying difficulties of the creator" and will thereby "demonstrate the basic motives in these attempts to satisfy the individual instincts."

Janota (1924), in discussing Prinzhorn's view regarding the difficulty of diagnosing a psychosis from a patient's drawing, contends

that such drawings reveal symptoms of the illness. According to Janota, the diagnostic difficulty rests in the evaluation of the creative expression as a whole. He states that one should look for defect in the form and content of the drawing, just as one does in the case of speech; it is only by this analytic approach that creative works may reveal characteristic attributes and thereby aid in diagnosis. Pfister (1923) maintains that *artistic appreciation* may itself have diagnostic value. He states (p. 204), "Tell me whose works amongst the expressionists you are enjoying and I will tell you who you are. For only he can understand the artist whose Unconscious speaks the same language as the artist's own Unconscious." Pfister elsewhere (1934) reports an experiment in which 431 psychotics were asked to draw 8 designs with colored crayons; an analysis of the designs in regard to color and movement yielded results of diagnostic value for the different psychoses. Karpov (1926) points out that if one understands the process of creative activity, one sees particular symptoms of illness in it which may be lacking in other aspects of the total clinical picture, but which at the same time are of considerable diagnostic aid.

The intimate relationship between art and mental derangements is discussed by Plaut (1928) under the term "psychopathography." He agrees with Prinzhorn that art is not the product of sanity or insanity, but the expression of the whole personality. Heyer (1929), in a paper read at the 4th German Congress of Psychotherapy, contends that drawings are more direct expressions of psychological phenomena than the spoken word, and consequently can be used to advantage in psychoanalysis. He argues that they should be considered not as art but simply as a means of expression during analysis, particularly as an expression of the "collective unconscious." Heyer elsewhere (1933) discusses the use of both drawing and writing as a supplementary psychoanalytic method, and attributes its introduction to Jung in 1923. He reports (1933: 252) that Paneth (1929) was concerned with the method of automatic or quasi-automatic drawing as a supplementary analytic technique later than but independently of Jung. Heyer reproduces 37 plates of drawings, made by 12–15 patients, chiefly neurotics, depressives, and schizoids. One is a "*mandala*"—a highly stylized and symbolical design which was started in the center and elaborated centrifugally in a very decorative and symmetrical fashion; the original, approximately 30 inches in diameter, required several months to complete. Such a "mandala" is considered by psychoanalysts to be of especial importance in indicating the workings of the "unconscious."

In the "commentary" to a text on Eastern art by Wilhelm (1929), Jung discusses the mandala or "magic circle" at great length, pointing out its independent occurrence and symbolic meanings not only in the East but also in European art since the early Middle Ages. He reports (1929: 32) that he has found many mandala drawings among the insane as well as among his own patients. Some have danced instead of drawn the mandala. Jung continues, "The patients themselves can say little about the meaning of the mandala symbol. They are only fascinated by it, and find it in some way connected with their subjective condition, and find it expressive and effective." Jung states that the "golden flower," the subject of Wilhelm's text, is a mandala symbol which he has commonly found among his patients, "drawn as a regular geometrical ornament, or subjectively as a flower which grows from a plant." He reproduces 10 representative mandalas, drawn by 7 male and 3 female patients during psychoanalytic treatment. All occurred spontaneously and without the slightest Eastern influence. The occurrence of the mandala design in such widely differing groups is said to illustrate "the parallelism of Eastern philosophy with unconscious European ideation." Jung has elsewhere termed this common substratum the "collective unconscious." In his "Collected papers" (1920: 41), Jung reproduces a mandala-like drawing of a mystic cosmic system made by a somnambulist.

Emery (1929) employs the following psychoanalytic color symbolism in interpreting the results of an experiment on color preferences: green—maternity, "womb fantasy"; blue—male; violet—royalty, mystery, dignity, penitence of Church, and possible feminine meaning; yellow—disagreeable side of life, linked with anal-erotic pleasures of early childhood; red—represents all that is stimulating, such as fire, love, blood, passion. Emery reports an experiment by Oberndorf in which it was found that a group of young student nurses preferred blue, indicating heterosexual interest; older social workers preferred green, which is interpreted as indicating interest in maternity. Emery also reports an occupational therapy experiment in which a box was filled with large skeins of wool in red, blue, green, yellow, and violet. Sixty patients in an out-patient psychiatric clinic were asked to close their eyes and at a given signal to open them and indicate the most attractive color. Emery reports that patients who had failed to progress beyond or had regressed to an infantile level, especially schizophrenics, chose yellow; 4/5 of the manic depressives and 2/3 of the compulsive neurotics chose red, thereby allegedly indicating a "death wish" or "desire to kill"; 1 feebleminded girl and all

cases of psychosexual infantilism chose green, indicating emotional immaturity.

Hutter (1934) maintains that the art products of schizophrenics reveal their "world view": a feeling of ruin, which is the central phenomenon in schizophrenia. He contends that such patients are not apathetic, although they may appear to be, and that from time to time the cataclysm of society or of the world or universe fills them with terror, which is shown in their paintings. Engerth, Hoff and Pötzl (1935) describe the case of an artist suffering from temporary hemianoptic scotoma and associated hallucinations who was asked by the physician to draw his hallucinations as an aid to diagnosis. A drawing of his own hallucinatory face showed small squares, little men, and "lightning" around it.

Merzbach (1930) describes the case of a 14-year-old boy, without talent for drawing, who drew obsessively while in a state of psychosis. Merzbach interprets the drawings as indicating a condition of periodic psychosis and as excluding the possibility of a diagnosis of schizophrenia. Schottky (1936) calls attention to a change in the style of drawings in the case af a 25-year-old female schizophrenic who had been a commercial artist. Schube and Cowell (1939) have recently developed a "Restraint-Activity index" for use in diagnosis. The patient's drawings are rated from 0 to 100 in each of the following categories: (*a*) productivity, including quantity of output, scale of drawn forms, mass of color, quantity of detail, and size of rectangle used for drawing; (*b*) design, note being taken of whether or not the arrangement exhibits anxiousness, carefulness, deliberation, expansiveness, or exuberance; (*c*) imagery, interpreted as the quality of vagueness, symbolism, or literal or intellectual realism; and (*d*) technic, or the mechanical process of production, note being taken of whether the style is cramped, tight, hesitant, or uncertain, or evinces speed, certainty, fluency, or breadth. In each case, ratings at the 0 end of the scale indicate predominance of "restraint"; those at the 100 end, "activity." The 4 ratings are averaged for the final "R-A index." Schube and Cowell report data on the application of the scale to 168 patients.

Zachry (1937) refers to an "experiment" carried out by D'Amico and Vassar at the Ethical Culture School at Fieldston, New York, under the supervision of the Commission on Secondary School Education of the Progressive Education Association. Zachry (1937: 35) reports, "it was found possible to take a series of pictures produced by any one student over a period of a year and trace in them the struc-

ture of that student's personality." This was done by "observing similarities and discrepancies in the theme of the content which a student chose, and by observing the qualities of technique and skill in order to determine their variations." Zachry (1937: 35) adds, "It is important to recognize here that symbols, represented through color, form, movement, and content, have more than their artistic context and may also be the expression of the various needs which an individual is seeking to answer."

Head (1926) describes four drawing tests as part of a series for examining aphasic patients. These tests include: (1) drawing from a model, such as jug or vase, and subsequently reproducing the drawing from memory; (2) drawing to command, the patient being requested to draw an elephant, selected because its salient features, such as trunk and tusks, are so obvious that their omission "clearly indicates defective powers of formulation"; (3) drawing the ground plan of a familiar room; and (4) drawing anything that comes to the patient's mind unprompted. Several specific differences between the responses of aphasics and normals to these tests are reported and illustrated with case studies. In a paper presenting a schema for the examination of organic cases, Mayer-Gross and Guttman (1937) describe a number of tests and other standardized observations. Under the heading of "motility" they include drawing—"Can he draw on request a cross, triangle, house, man, or elephant? Can he copy simple drawings? Can he trace?" (1937: 450.) At the Virginia State Colony for Epileptics and Feeble-Minded, J. N. Buck* has developed the "JNB Drawing Test," in which the patient is asked to make successive drawings of a house, tree, and person, the drawings being scored with respect to attitude, plan, details, proportions, perspective, lines, self-criticism, drive, time, and subject's comments. No results, however, have been published to date.

Claude and Masquin (1934) report the use of drawings in the case of a 54-year-old artist who was treated with malaria for general paresis. Under malaria treatment, the patient gradually began to scribble, then to make childish drawings, and slowly to regain his old technique, although the drawings never regained the originality of his former work. Borja (1938) concludes that in some cases of schizophrenia, the only way to discover symptoms is by means of the imaginative drawings of the patient. He reproduces 22 such drawings and discusses their use in diagnosis. Orenstein and Schilder (1938) report the use of drawings (copying 9 Gestalt figures) in the case of

* private communication to the writers.

19 schizophrenics undergoing insulin treatment, the resulting drawings indicating a "disturbance in Gestalt function" as a result of the shock.

Liss (1938: 97) discusses the following significant diagnostic criteria: (1) size—said to be "an index of inner attitudes toward dimension and physical stature" and to be "related to ego evaluations and attitude towards mass and space"; (2) line (including design, pattern, and form), which may be open and free or closed, repetitive, stereotyped, or ritualistic—fixity of pattern being said to indicate repression; (3) color—black and brown allegedly being associated with the "unconscious components of a depressive nature," although attention is called to the need for evaluating this criterion in terms of the specific society; (4) subject or symbol, the finished product being interpreted according to procedures of dream analysis or play techniques.

Pickford (1939) reports an analysis of a picture painted impulsively by a young male student, not trained as an artist. The painting was done in a fit of anger during a period of overwork. The interpretation, aided by notes written and dictated by the artist, is said to show how aggression was expressed chiefly through attacks on fantasies symbolized by the cardboard and objects drawn, and how various distasteful ideas were symbolized in the painting. Gutiérrez-Noriega (1940) emphasizes the diagnostic significance of drawings in the case of a schizophrenic; the drawings reflected changes in perception, vague and distorted or bizarre ideas, and psychopathological experiences. Characteristics of the drawings are said to be closely related to the patient's symptoms and to reveal "unconscious processes." According to James (1939), the type of spontaneous drawings is sometimes a clue to the nature of the disorder. Fontes (1938) also stresses the diagnostic function of such drawings. Rosanoff (1938) describes clinical tests for reading and writing, and discusses the symptomatology revealed in writings as well as drawings by the insane. Segal (1939) likewise discusses the use of art as a test of normality.

Baynes (1940) reports the use of dreams and drawings as diagnostic techniques in his psychoanalytic study of two borderline patients, who expressed the critical phase of their "psychotic conflict" in a series of drawings. Gutheil (1939) discusses the use of drawings and paintings of dreams "as a means for interpreting the artist's unconscious" (p. 204), although he points out that both artistic training and experience in dream interpretation are necessary. Drawings by different neurotic patients are reproduced and discussed psychoanalytically in connection with the respective case histories. Gutheil

calls special attention to the symbols of bisexual organs, called "lingams," one of which is reproduced in the text (p. 63). In their treatment of the clinical aspects of schizophrenia, Kihn and Luxemburger (1940) discuss the artistic productions of schizophrenic patients along with other diagnostic clinical data, such as sensory illusions, deterioration of cognition, disintegration and hallucinations of speech, abulia, and various kinds of delusions.

Nearly all of the above studies have been primarily concerned with drawings by adults. Several investigators have recently studied the use of drawings as diagnostic devices in the case of behavior disorders in *children*. In his "Psychology of early childhood," Stern (1930) suggests that drawing may become a useful means of interpreting character in children, and refers to Krötsch's similar emphasis upon its diagnostic value. Stern writes (1930: 368):

> "As soon as we look upon drawing as an expression-movement, its products become an important aid in diagnosis, disclosing under certain circumstances deep-seated qualities of the child's psychic dynamics. . . . In this sense Krötsch considers children's spontaneous drawings—especially when access can be had to a number of productions by the same child—as affording evidences of character. . . . Here we find a new, possibly very fruitful, means of interpreting character in childhood, not however before its application has been systematized."

In order to throw light upon the qualitative aspects of "intellectual growth" in young children, Isaacs (1930) reports detailed protocols of the behavior of children in connection with the Malting House School experiment in progressive education, carried on from 1924 to 1927. Among the activities reported are drawing, painting, modeling in plasticine and in putty, as well as making paper dolls and making objects with boxes, chairs, and the like.

Griffiths (1935) studied the spontaneous drawings, as well as imagery, ink-blot reactions, dreams, and original stories, of 50 English children 5–5½ years of age, with M. A. range of 3–4 to 6–9 and I. Q. range of 66 to 129. Various emotional and mental factors were revealed by the drawings and elaborations upon them and by the other material. Thirty-six drawings are reproduced. Freeman (1936) discusses the use of spontaneous drawings as a means of communication between certain socially maladjusted high-grade mental deficients and their physician. Cases are cited illustrating the application. Traube (1937) asked a group of six 14-year-old children to draw what they had done the previous Sunday and claims that certain traits of an emotional or intellectual nature were revealed by such drawings. Thus a predominance of geometric forms or the absence of living

figures was related to retardation. The number of details increased with age. Color played an important role, depression, for example, being indicated by a neglect of color or by a preference for brown or violet. The contents of the design are said to possess symbolic value, *e. g.*, the use of bars by a child who had been too strictly brought up. As a check on the theory that these drawings were pathognomic of certain defects, Traube tested a group of normal children and found that in most instances the pathological characteristics were absent.

Bender (1937a) discusses the art project in the children's observation ward at Bellevue Hospital in New York City, originally under the guidance of Bernard Saunders. She points out, among other things, the diagnostic value of the material obtained. Bender has also published a series of articles dealing with the use of Wertheimer's figures in an analysis of the motor factor in problem children and abnormal adults; her various papers, to be discussed in a later article of the present literature survey (Anastasi and Foley 1941b), are summarized in her recent monograph, "A visual motor Gestalt test and its clinical use" (Bender 1938). Curran, in his talk at the second conference on "Psychopathology and art" (*cf.* Anonymous 1938a), sponsored jointly by the Psychiatric Division of Bellevue Hospital and the Federal Art Project, W.P.A., also stressed the diagnostic value of adolescent drawings. Curran elsewhere (1939b) discusses the functions of artists working in institutions with behavior problems or psychotic patients. He suggests that such artists should adopt an attitude of tolerance, take detailed notes while the patients are painting and afterward, permit the patient free expression in his work, encourage him by exhibitions, and acquire knowledge of the principles of psychiatry and of their individual patients. Curran cites the Bellevue art classes, points out their value in diagnosis, and states that similar classes should be encouraged in other institutions. Again referring to the Bellevue art classes, Curran and Schilder (1940) assert that in drawing, aggressive patients use bright colors, while those involved in problems of death and destruction use dark shades. They further point out that modeling may express a function rather than a definite object and that it may also demonstrate the child's curiosity regarding his own body.

Stavsky (1938) gives a highly psychoanalytic interpretation of the spontaneous drawings of a house and tree made on the blackboard by a child (I. Q. 133) while resting for the second part of the Stanford-Binet. Morgenstern (1939) likewise discusses the symbolism of children's drawings, pointing out that as in the case of their

games, stories, and dreams, the real content of the drawings differs greatly from the manifest meaning. Morgenstern analyzes the drawings of two 9-year-old boys, one bordering on dementia praecox and the other a case of anxiety neurosis and total psychogenic mutism. Birds were used by both subjects in different ways to symbolize their anxieties. Another recent psychoanalytic paper by McIntosh (1939) reports a study in which 3 maladjusted boys and 3 maladjusted girls (C. A. 6 to 13, I. Q. 68 to 126) were asked to draw anything they liked and then to tell the analyst about the picture. Interpretations were made by the analyst "when the drawings and associations seemed to justify them." Edelston (1939) reports an analysis of a case of neurotic conduct disorder in a 7-year-old child, whose drawings were studied in relation to her phantasies and to the situations contributing to her difficulties.

The use of art productions as diagnostic aids in child neuroses has recently been reported by Harms (1940). Three types of procedure were followed: (1) "line analysis"—an exercise in abstraction in which the subject is required to draw lines representing the "experience value" of prescribed words, such as "dance," "fear," or "work"; (2) "affective release"—the representation of the affective significance of such words as "joy" or "pain" in color and form; (3) "fact test"—the representation in actual pictures of the subject's replies or other reactions to specific questions, such as "What are you most afraid of?" or "What do you love most?" In his discussion of the results of such techniques, Harms emphasizes the diagnostic significance of the material.

Spoerl (1940) studied the drawings of 11 retarded children, ranging in age from 7 to 9–10, and in I. Q. from 52 to 98; some of the children were described as decidedly psychopathic. The drawings, in pencil and crayon, included illustrations of stories, copies of pictures, and free choice drawings. The products were submitted to a total of 164 judges (but not all judges were given all drawings), who were asked to sort the set of drawings into piles, each representing the work of a single child. The results were considerably better than chance, indicating a certain consistency in the child's work. When the judges were subsequently asked to match brief written personality sketches of the children with specimen sets of drawings, the results were again better than chance, although certain subjects were judged with much greater accuracy than others.

Ackerman (1937) describes an experimental play situation which may be used for the study of constructive and destructive tendencies

in children, the latter being defined in terms of types of building or breaking toys in the play situation. A correspondence was usually found between the child's socially constructive and destructive behavior and his performance in the experimental play situation; hence the value of the method as a diagnostic and prognostic aid. In a later paper, Ackerman (1938) reports the application of this method in a study of the constructive-destructive tendencies of groups of well adjusted, maladjusted, and delinquent children. Ackerman concludes that as a child grows older in a well adjusted direction, there is an increase of activity of the "flexible type"; as he grows older in a maladjusted direction, there is an exaggerated increase in both constructive and destructive activity of a relatively rigid type.

A somewhat related psychodiagnostic method, the "toy test," is reported by Bolgar and Fischer (1940) in the case of 100 randomly selected adults. The subjects were asked to do whatever they liked with a standardized set of simple children's toys, including all essential objects which constitute human surroundings, such as houses, trees, vehicles, buildings, bridges, persons, animals, and the like. Behavior and verbalizations were recorded during the experiment, and the finished product was photographed or sketched. On the basis of such an analysis, it was possible to establish normal average reactions and characteristic deviations, as well as certain reaction forms typical of clinical groups. Bolgar and Fischer point out that the main advantage of this method is that it is non-verbal and that it deals with directly representative material which can be easily handled, regardless of intelligence, education, or specific experience.

Finger painting has also been recently used for diagnostic purposes. Drewry (1936) reports its use with adult psychotics, both when the physician sat with the patient during the painting and discussed it with him, and when the painting was done in occupational therapy and subsequently discussed. Drewry is doubtful about its diagnostic value; the results are reported to be inconclusive and to be actually misleading in some cases. Previous art training must be taken into consideration. Mosse (1940) has recently reported results of finger painting analysis in the case of 30 neurotics, 21 male and 9 female, 25 of the patients being from Bellevue Hospital in New York City and 5 from his private practice. Painting-analysis was used in conjunction with free association and psychoanalysis. No design was found to be specific for a particular type of psychoneurosis, although differences were found between psychotics and neurotics. Mosse contends that finger paintings are of more diagnostic value in the neuroses than

psychoses. Additional studies dealing with children's finger painting will be discussed in the following section on therapy.

Several writers have stressed the diagnostic value of *"automatic drawing and writing."* Mühl (1930), for example, believes that such material will reveal, in conjunction with psychoanalysis, "unconscious trends," "conflicts," and "repressed ideas." As early as 1912–13, Pfister (1912, 1913a) reported analyses of selected cases of cryptolalia and cryptography, and discussed the use of cryptographic analysis in cases where dream analysis was difficult. Such automatic cryptic writings, or cryptograms, are said to afford excellent materials for psychoanalysis. Schultze (1938) reports the successful use of automatic drawing in place of the traditional association method in the case of a schizothymic female neurotic. Erickson and Kubie (1938) have recently described the use of automatic drawing in the interpretation of a state of acute obsessional depression. The patient, a young girl, made typical "doodling" figures during the course of a psychoanalytic interview, and subsequent investigation revealed that such figures had been made by the patient since her emotional disturbances began. The case is discussed from a psychoanalytic viewpoint, and possible significances of the technique for psychoanalysis, such as a means of disclosing hidden "conflicts," are pointed out. Three typical figures are reproduced.

Arundel (1937), in his recent popular book of "doodles," has also emphasized their value in diagnosis, and reproduces doodles by a number of famous contemporary figures. Arundel describes such automatic drawings and writings as "accurate pictures of the Subconscious Mind" and as "psychic blueprints of man's inner thoughts and emotions." He reproduces a "Pixillation Chart" for aid in their interpretation, but points out that they cannot be accurately analyzed without a knowledge of the past experience of the maker. Arundel refers to the work of Mühl, and concludes, (p. 71) "psychiatrists agree that the designs in a doodle cannot be actually interpreted, but the character of the design, the manner in which it was made, the depth and harmony of lines, and the manner in which the designs, figures and words are coördinated with the activity of the person at the time the doodle was made are highly significant." A more detailed and objective study of such automatic drawing, although with less clinical emphasis than in that of Erickson and Kubie reported above, was made by Maclay, Guttman, and Mayer-Gross (1938), who analyzed approximately 9,000 doodles submitted in a contest to an English newspaper. The materials were analyzed with respect to content as well as conditions under which they were made.

We have already seen that certain writers, such as Simon (1876, 1888), Pérez (1917), and Rosanoff (1938), have also stressed insane *writing* as indicative of clinical syndrome. Marcé (1864a), in his discussion of the diagnostic value of such writings, points out the need for comparison with the (control) writings of the patient before the onset of the psychosis as well as the need for information regarding the patient's education; writings are said to be more indicative for better educated patients. Such writings, according to Marcé, can be regarded in two ways: (1) as expressions of delusive ideas, *i. e.*, in terms of content, and (2) as graphic expressions, or design, *e. g.*, shape, arrangement and assembly of letters, mode of arrangement of words, lines, pages, etc. He discusses the differential characteristics of each form of insanity in these terms, pointing out the value of such data in legal medicine. A second paper (Marcé 1864b) also reports cases in which the study of the ideational content and graphical representation in insane writings was of diagnostic aid, the paper concluding with a survey of the characteristics of such writings in the various forms of insanity and with medico-legal applications.

Diagnosis and prognosis are among the various problems connected with insane writing treated by Raggi (1874). He concludes that their diagnostic value is limited; they must be compared with former writing; normal writing does not indicate the absence of mental disorder; and they should be combined with other symptoms for accurate diagnosis. Raggi also maintains that writings are of value in establishing the general form of the disorder, and that they may often suggest the best means of treatment. In fact progress of recovery itself may be indicated in the writings. Régis (1882) also reports that writings, apart from their orthographic characteristics, afford an excellent insight into the mental state of the patient. He adds that individuals are usually less reticent in writing about themselves than in talking, and concludes that in most cases the insane show remarkable gifts for expression in writing and that such writings often portray their symptoms with admirable clarity. Morselli (1894. vol. 2, 494–558) also treats the writings as well as the plastic arts of the insane from a purely diagnostic angle. He discusses writing movements, the finished product in handwriting, and the content of the writing, and considers these the most important material evidence of insanity.

Lauzit (1888), following a survey of most of the literature in insane writing prior to 1888, states as his chief conclusion that writings are a useful diagnostic device. He adds that in making the diagnosis,

one should observe all the details, including content, arrangement of writing, manner of folding paper, and orthography, as well as such signs as numerous erasures, deformation of letters, underlined words, and use of capitals. Garnier (1894) points out that Pinel, Moreau de Tours, and Marcé all affirmed their belief in the use of insane writings for diagnostic purposes. Garnier discusses both (1) the graphological possibilities, which he feels are not so convincing since the different insanities could hardly modify the individuals to the point that all those of the same group would write alike, and (2) the value of the writings as a mode of ideational expression. The following clinical types are discussed, with examples of original letters, prose, and poetry: graphomaniacs (4 cases), chronic deliriants (5 cases), maniacal state (2 cases), general paralysis and dementia (3 cases). Garnier concludes that mental imbalance may show up with more clearness in writings than in any other mode of expression, and indicates some of the attributes of writing characteristic of delirium and degeneration.

Lombroso (1895a) discusses the handwriting of the insane, with numerous illustrations, three of which (by monomaniacs) combine drawing and writing. He points out that the introduction of drawing in writings is especially pronounced among monomaniacs, who experience vivid images which they cannot describe in words and hence resort to drawing. Wundt (1896: 320–321) considers the writings of the insane to be an excellent record of the "decay" of intellectual functions. He cites a "privately printed" book which showed progressive change from opening sentences "correct in form and expression," through description of hallucinations, linguistic solecisms and disconnected associations, to the last few pages on which "there is not a single sentence that is brought to its correct grammatical conclusion." Ballet's comprehensive treatise (1903) contains a detailed discussion of language disorders. He states, (pp. 152–153) "the writings of the insane sometimes take the form of simple notes reflecting their special ideas. These are certainly the most interesting from the psychological point of view. Often they are veritable manuscripts, a monograph on the illness written by the patient himself." He points out that in their minds such essays "are destined to prove the rectitude of their judgment, but show, on the contrary only the lack of their equilibrium and intelligence." Ballet continues (p. 153), "The mystic testaments and especially the holographs written by the insane can furnish useful elements of medicolegal appreciation through writing, form, style, contents, sometimes

reflecting confirmed mental disorders. Comparative examination with previous writings of the patient is a necessary thing."

Köster (1903) discusses in detail the use of writing as a means of diagnosing various mental diseases, and cites extensive case histories to illustrate its use in different syndromes. Capgras (1911) holds that the pathological nature of certain insane writings aids diagnosis, but that normality of writing does not negate the possibility of insanity. This, he adds, is especially true in the case of paranoia and dementia praecox. Del Greco (1935) points out some of the psychodiagnostic possibilities and limitations of writings. He maintains that apart from a few cases of confusion, disorders of perceptual and ideational representation, or complete deterioration, one cannot diagnose psychopathy from literary products. One must always consider the individual in relation to his times and cultural environment. The use of writings in psychiatric diagnosis is also discussed in the recent paper by Fontes (1938). Kerschbaumer (1940) reports case studies of 4 patients who wrote poetry spontaneously, with sample poems by each. The patients included one paranoid dementia praecox, one variously diagnosed as manic depressive or psychopathic personality, one constitutional psychopath with sexual perversion, and a much improved case of unclear diagnosis. The characteristics and diagnostic value of the poetry are noted, Kerschbaumer concluding (p. 156), "poetry, prose, drawing, sculpture—music belongs here too—are not only useful for the patient as a means of emotional expression and relief from tension but are useful for the psychiatrist to gain a better understanding of the psychic structure in the psychotic and non-psychotic."

Legrün (1930) discusses a case of excessive variability of handwriting as a graphological index of psychopathy. Schönfeld (1933) contends that the "writings" of pre-school children are graphologically as important as those of adults, since they reflect the child's personality and indicate clearly an inhibited or maladjusted child. Examples of "scribblings" by 5 children are reproduced. Fanta (1938) also indicates the diagnostic importance of graphology in the case of problem or criminal youths. He analyzed the handwritings of such children without knowing the psychiatric diagnosis, and reports accurate results. Fanta distinguishes between the "mentally poor" and the "mentally sick," and graphologically divides the latter into those with "weak will power" and those with "strong urge or passion." He reproduces 11 samples illustrating the mechanics of the writing of the various types.

Mandowsky (1934) likewise attempts to study the general appearance and details of handwriting in an effort to obtain diagnostic indices of mental disorder, and reproduces 22 illustrations of writing. He reports an instance in which 12 members of his seminar attempted to judge the handwriting of 15 subjects (1 sane, 14 insane). He also discusses 25 specimens of schizophrenic writing with reference to their classification into 3 major sub-groups. On the basis of this varied work, Mandowsky concludes that from handwriting alone one cannot tell whether the writer is insane, although one can determine the direction of his possible disease. On the other hand, if one knows that the writer is insane, his handwriting can help to diagnose the case. Mandowsky reports that of more than 200 cases studied by him, only 2 were obviously written by the insane. Mendelssohn (1938) shows how personality changes during the course of psychoanalysis are reflected in the person's handwriting, psychograms, and drawings and wax-figure models of dreams. Cases are cited to illustrate the diagnostic use of these media in indicating progressive changes in the course of psychotherapy. Following Klages' system of graphology (Klages 1935), Lewinson (1940) analyzes the characteristic "graphic syndrome" in 3 types of psychoses. She maintains that analysis of handwriting is a valuable psychodiagnostic technique although she admits that her own data are inadequate and her study primarily exploratory. Lewinson suggests the possibility of deducing by this means personality types which are predisposed toward the 3 types of psychoses, the trends being detected in the handwriting long before the onset of the disorder.

The Psychiatric Approach: Therapeutic Value

Apart from the use of artistic productions by the insane as purely diagnostic indices, there remains an additional psychiatric use which is distinguishable from though related to their use in diagnosis, viz., their therapeutic value. Although there is a certain amount of unavoidable overlapping with the previous section, particularly in the psychoanalytic papers, an effort will be made to consider here only those papers in which the therapeutic value of artistic behavior in the abnormal is explicitly stated or clearly implied.

Let us first consider the use of various forms of art therapy with *children.* No attempt will be made to review the extensive literature on play therapy (play, puppet, drawing, painting, finger painting, plastic art, etc.); only those studies in which such therapy involves a certain amount of free, imaginative and creative activity on the

part of the child will be treated. Levy (1934) discusses the use of art therapy in treating children's behavior problems, especially those arising from "mental conflicts." Among the media employed were: water colors, oils, clay modeling, plasticine, finger paints, colored pencils, and soap. The products were made spontaneously, although a minimum of 1 hour 3 times per week was required. Among the advantages of such therapy, Levy mentions its facilitation of recovery, the possibility of its use during negativistic phases, and its use with younger children who have difficulty in verbalizing. The following difficulties are discussed: it cannot be used on all children, necessitates frequent visits, requires passive coöperation (non-interference) from parents, and cannot be readily combined with other forms of therapy. In a review of recent techniques and instruments for mental hygiene diagnosis and therapy, Strong (1940) surveys the work on group activities and play and art therapy along with other therapeutic techniques.

Potter (1935) also discusses play therapy in children. He points out that children present chiefly psychoneurotic and behavior problems, the more severe psychoses being rare and the symptoms seldom crystallized into well-defined reaction types. Among the aims of psychotherapy in children, Potter mentions establishment of rapport; release of emotional tension through affording the child an opportunity to "express his conflicts" verbally or through observed play; analysis of behavior disorder or neurotic symptoms in terms of the child's emotional conflicts and use of such knowledge in guiding those responsible for his care and training; explanation to the child of his symptoms as these relate to emotional conflicts; and aid in "adjustment to reality." Sell (1938), in his popular article, "Saving children from their pasts with the paint brush," describes the use of painting with maladjusted and delinquent children at the Hawthorne Cedar Knolls School at Hawthorne, New York. The painting was done under the supervision of Harold Goldfinger, an artist teacher of the Art Teaching Division of the Works Progress Administration who was subsequently connected with the Bellevue art project, and the resulting products were later exhibited at the New School for Social Research in New York City. Sell reproduces 6 of the paintings, and discusses these and other cases in detail.

Appel (1931) describes the use of story telling, reporting dreams, and drawing as sucessful techniques for establishing rapport with problem children, such as post-encephalitics. Among the specific procedures followed were included: interpretation of ink blots and

"blottoes," drawings of a house, of different persons in the house, of the child himself, his nurse, physician, etc. The application of the technique is illustrated in the case of an 8-year-old post-encephalitic girl. Griffiths (1935), in her previously mentioned study of the spontaneous drawings, associations, and imagery of 50 English children 5–5½ years of age, concluded (p. 225), "the opportunity to abreact, through the symbolism of drawing, what is not easily otherwise expressed, is beneficial to inhibited children, as is also the accompanying desire to tell about what they have made. Free drawing has therapeutic value." Freeman's paper on "Drawing as a psychotherapeutic intermedium" (1936) includes a discussion of cases in which socially maladjusted, high-grade mentally deficient children were asked to draw their "thoughts" on successive interviews. The resulting drawings proved to be of aid in correcting the behavior disorders.

Bender and her associates in the children's observation ward at Bellevue Hospital have made extensive contributions to the literature on art therapy in children. Among the various psychotherapeutic group activities described by Bender (1937b) are the different art projects, whose purpose is to furnish group experiences whereby the children can express their aggression without feeling guilty and can otherwise be relieved of their negative emotional attitudes of guilt, anxiety, apprehension, uneasiness, inferiority, and insecurity. Three major projects are discussed: (1) the puppet project, as described below; (2) the music project, in which homogeneous age groups engage in group singing, rhythm band, singing games, and individual performance on an "amateur" hour; and (3) the art project, originally supervised by Bernard Saunders. The latter project affords a contact with the child who might otherwise find it difficult to express himself, provides a continuous record of symptomatic development and improvement with therapy, and provides an objective and socially approved means of expressing aggressiveness in place of overt antisocial behavior on the one hand or "phantasying" on the other. The group response to the child's paintings is emphasized, including not only the reaction of adults, such as the artist and psychiatrist, but also the reaction of other children.

Bender and Woltmann (Bender and Woltmann 1936; Woltmann 1940) describe the therapeutic use of puppet shows, permitting the expression of (1) aggression by or towards the child and (2) problems of the child's love relationship with parents and siblings. The puppet project includes observation of the play (the most successful of which

were taken from folklore), subsequent discussion of the play with the psychiatrist, as well as making puppets, writing and conducting plays, etc. The authors point out that the group activity, as well as the relatively impersonal nature of the puppets, leads the child to express himself more freely than he would in a personal interview. The article is followed by comments by Wexberg objecting to many of the psychoanalytic interpretations. Bender and Woltmann (1937) elsewhere discuss the use of plastic material as a psychiatric approach to emotional problems in children. Each group of 5–8 children was given plasticine and an armature and told to make anything they wished. The authors discuss 20 illustrative cases, the interpretations being partly psychoanalytic and partly in terms of the objective past experiences of the child. Among the advantages of plastic over graphic expression are: coördinated movements of both hands are employed, the third dimension can be reproduced directly, and a single medium is used directly rather than paper and pencil. Bender and Woltmann conclude (p. 299), "Plastic material constitutes a suitable outlet for aggressiveness, counter-aggression, destruction and construction. It has specific possibilities in helping children solve problems such as body composition, body posture and curiosity towards anal and genital regions. It serves as a medium through which the child expresses problems of his own in relation to his body, to family and to surrounding society."

Another paper by Bender (1937a) deals with the art project in detail and again emphasizes the therapeutic value of artistic expression in establishing rapport, acting as a "catharsis" for aggressive impulses, serving as a socializing force, affording an opportunity to express the impulses for motor activity and for creation and experimentation with forms, as well as yielding a clinical record of progress and improvement. Five illustrative case histories are cited. In a description of the Bellevue ward for adolescents, Curran (1939a) mentions such activities as art classes, dramatic activities, educational projects, story-telling, bead work, etc. Curran also stressed the therapeutic value of drawing in his talk at the second conference on "Psychopathology and art" in New York City, October 31, 1938. Similarly, in his article on "Art techniques for use in mental hospitals and correctional institutions" (1939b), previously discussed, Curran emphasizes the therapeutic as well as the diagnostic function of art classes such as those at Bellevue. In a report of group therapy with children and adolescents, with special reference to discussions, drawing, modeling, playing with dolls, and the writing and production of

plays, Curran and Schilder (1940, 1940–1941) maintain that these activities permit free and acceptable expressions of aggression and love. A recent popular article by O'Bryan (1939) likewise refers to the Bellevue work, and indicates its value as a means of gaining rapport with the child, revealing his phantasies, and often showing what therapy is needed.

Despert (1936–1938) also discusses technical approaches to the study and treatment of emotional problems in children. Among the techniques considered are: the story—a form of directed phantasy—, use of a knife under definite prescribed conditions, drawing, "collective phantasy," and playroom activities. In her later book (1938), Despert synthesizes the various methods of child psychotherapy used at the New York Psychiatric Institute and reported in her earlier series of articles. Edelston's paper on "The analysis and treatment of a case of neurotic conduct disorder in a young child illustrating the value and use of drawing in child guidance technique" (1939) is concerned with the clinical history, treatment, and progress of a 7-year-old girl who was a decided behavior problem. The child and her surroundings are described, with special attention to the drawings which she made and to their relation to her phantasies. The drawings proved to be of direct therapeutic aid.

Among the first psychoanalysts to employ drawings in working with children was Anna Freud. In her monograph on the "Technic of child analysis" (1928), she states (p. 24), "A further technical aid, which next to the use of dreams and day dreams comes to the fore in many of my child analyses, is drawing, which for the time being in three of my enumerated cases almost replaced all other communications." She adds (p. 25), "the child discloses itself as an eager dream interpreter, who produces an abundant flow of dreams and, at the same time, furnishes a series of interesting drawings, from which conclusions may be drawn concerning its unconscious impulses." Klein (1937), in her discussion of the use of play therapy in the psychoanalysis of children, reports 3 cases in which drawings were used as a basis for analysis. Egon, a 9½-year-old shut-in, obsessional and pre-schizophrenic type, produced lines and scrawls which were interpreted as indicating sexual phantasies. Greta, 7 years of age, drew differently sized houses and trees alternately in an obsessive way, the drawings being interpreted psychoanalytically as representing her mother, father, herself, and brother, as indicated by the differences in the sizes, shapes, and colors of the drawings and by the order in which they were drawn; the drawings were assumed

to reveal her anxiety and sense of guilt. Ilse, aged 12 and of borderline mentality, could be analyzed only through her apparently unimaginative drawings done with compasses, in which measuring and calculating played an important role; the form, colors, and dimensions of the component parts were alleged to represent different people and to reveal the child's anxiety and sexual inhibitions.

English (1936), after discussing the general problem of the psychoanalysis of children, which he states was initiated by Sigmund Freud in 1909, and after discussing the various psychoanalytic schools of thought with respect to problems of child analysis, reviews the "art technique" of Anna Freud and the "play technique" used extensively by Melanie Klein. In connection with the "environmental approach," English discusses "recreational therapy" through art classes, dramatic clubs, etc., all of which are conceived as techniques for "self expression." The previously discussed work of Bender and her associates is also relevant at this point. Rogerson (1939) has also recently summarized the history of play therapy, including the work of Melanie Klein, Anna Freud, Levy, and Bender and Woltmann. Rogerson cites 4 original case studies, and concludes with a theoretical discussion of the relationship with the therapist, fantasies expressed in play, and reasons for improvement.

Liss (1936) reports that observations in classrooms where progressive education was employed suggested the possibility of using art work as one would dream analysis. Three illustrative cases of children are described: a girl's dramatization of her difficulties through a puppet show; a 9-year-old boy's painting and drawing accompanied by his own running comment, continued for 3 months, and reflecting a gradual solution of his emotional difficulties; and the spontaneous creation of a story by a 12-year-old boy. Each case is interpreted in terms of the child's emotional "conflicts," which are largely resolved by the art therapy. Morgenstern (1939) also treats children's drawings, as well as their games, stories, and dreams, from a psychoanalytic viewpoint, pointing out their therapeutic importance. McIntosh (1939), having asked his subjects (3 boys and 3 girls, C. A. 6–13, I. Q. 68–126) to draw everything they liked, requested them to tell the analyst about the pictures. Improvement was noted in all cases, and was marked in some, even though the analysis was not carried on long enough to show maximum results. McIntosh suggests that such a method would be superior to verbal free association in cases of children and other patients who are more inclined to draw and talk about their drawings, and that it would be especially suitable for

children who are too old for the analytic play techniques. A popular article by Malcolmson (1938) relates how the problem child's fears and worries may be overcome by having him "paint his bogey man." In an article on physically handicapped children, Mendenhall (1940) points out that participation in music, rhythmics, dramatics, folk dancing, clay modelling, and painting is one of the best ways to help such children to develop socially and emotionally.

The psychiatric use of *finger painting* is considered by Shaw (1934) in a general book on the use of finger paints. The author cites (chapt. 5) several cases of children who stammered or had obsessive fears or similar difficulties, and who recovered after trying finger painting. The therapeutic value is claimed to come from enabling the child to express the cause of his disturbance. Shaw discusses (chapt. 6) the use of finger painting to aid the child in understanding arithmetic, geography, etc., and reports individual case studies. Chapter 10, "A psychologist looks at finger painting," written by Henry C. Patey, contains objections to the use of universal symbolism. After pointing out that a symbol is a "reduced cue" to be understood in terms of the individual's particular experience, Patey discusses the use of finger painting in free association, "mental catharsis," play techniques, and direct recall and verbal expression—the child talking into a dictaphone when interpreting the finger painting. Shaw's work, originally done at her progressive school for children in Rome as a part of the art education program, has more recently been carried out in this country, and has been copied by a number of child psychiatrists and educators.

Lyle and Shaw (1937) point out that finger painting is an unusually suitable medium for stimulating the expression of fantasies. It affords greater freedom and facility than most mediums. Since only the larger muscles are called into play, it can be used with very young children with ease. It requires less precision in handling, thereby affording a release rather than an increase of tension. It also affords satisfaction lacking in other art forms, such as the permission to play with mud, or "socially acceptable dirt." Working at the Southard School, a non-profit corporation affiliated with the Menninger Clinic at the University of Kansas, Lyle and Shaw describe a number of cases of destructive and other forms of fantasy expression, reading inhibition, etc., which were successfully treated by the use of finger painting. Two instances are reported of improvement in speech and general attitude in the case of children who at the time of enrollment would

not speak at all, although the authors are careful to point out (p. 81) that "both of these children were worked with intensively in a number of ways, so that it would be impossible to state what part of their progress could be attributed to the release obtained through painting."

The previously reported papers by Levy (1934) and by Bender (1937a) likewise report the use of finger painting, among other mediums, in the case of problem and mentally deficient children. Obrock (1936) points out the advantages of finger paints in creating pleasant forms of rhythmic hand and foot exercises for spastic cases; there is also relaxation from constant dipping in water and from pleasant tactual sensations. Finger paintings likewise stimulate the child's imagination in interpreting shapes. Obrock states that the child's paintings may not always be beautiful, but may frequently be sinister and horrible, an "outward sign of inward emotional disorder," and concludes that "this chart of the child's emotional condition may be an aid in his treatment." Curry (1937) reports the use of finger painting as an accessory to story telling in the case of normal and problem children, the narrator altering the picture successively as he tells each new part of the story. An illustrative story about "farmer Brown," with 4 successive stages of the picture, is given.

Spring (1935) gives a psychoanalytic account of the finger-painting activities of a 10-year-old boy who had stammered severely since the age of 5, gave evidence of marked hatred of his mother, and was generally irritable, unfriendly, and uncooperative. Spring reproduces 2 of the boy's pictures, which he maintains show clearly (*sic*) "the unconscious identification of words with feces, common to stammerers." A description is given of the boy's progress in social and educational readjustment, of his development of better speech control, and of the improvement made in various neurotic habits. Spring reports (p. 257), "according to the teacher, 5 of 6 stammering children she has worked with showed marked improvement, though therapy was never a conscious aim." Spring feels that "the invitation to smear offers a situation suited to overcoming the sense of guilt connected with anal wishes." Gitelson (1938) reports the inclusion of finger paints and other plastic materials among the toys in a play room, but discusses no concrete results.

Drewry (1936) reports the use of finger painting for therapeutic purposes in the case of adult psychotics. Illustrative cases are described, Drewry concluding that the patients were more relaxed after the painting, and gained a better understanding of their difficulties.

Mosse (1940) discusses finger-painting analysis in the treatment of adult neuroses. He concludes that such a technique, in conjunction with free association and psychoanalysis, is more successful with neurotics than with psychotics. Fleming (1940) reports the use of finger painting in the treatment of 17 psychotics, aged 16 to 45 with an average of 25, distributed among the following syndromes: anxiety hysteria, conversion hysteria, pathologic personality, obsessive-compulsive neurosis, schizophrenia, and reactive depression. Special training or experience ranged from grade school to higher studies in art, music, or creative writing; only 3 had had training in finger painting. Fleming concludes that, along with free association, word association, ink blots, story telling, and play, finger painting offers an outlet for tension and promises to be a valuable medium for enlisting fantasy material of remarkable spontaneity and significance.

In the strictest sense of the term, nearly all of the *psychoanalytic studies* reported in the various sections of the present paper might be said to be relevant to the problem of the therapeutic use of the patient's artistic productions. This is particularly true in the case of those psychoanalytic studies reported in the previous section on "diagnostic value." There remain, however, certain additional psychoanalytic papers which have stressed the theoretical aspects of such therapy or have reported cases of the use of art products in "catharsis," expression of unconscious phantasies, etc. Prinzhorn, Gesemann, Kronfeld, and Sach (1925) point out that psychoanalysts regard art as an auto-catharsis for the neurotic. Pfister (1913b, 1917) reproduces 8 drawings and paintings made by an intelligent 18-year-old boy with extreme introverted tendencies in the course of psychoanalytic treatment. The patient's associations to each picture were recorded, and both pictures and associations are interpreted in terms of his complexes. One of the pictures—that of a church—is reproduced by Kempf (1920), who psychoanalyzes this and a wide variety of other artistic productions. Bertschinger (1911) reproduces 29 drawings of people and weird animals, produced during psychoanalysis by a female hysteric with dementia praecox symptoms. The drawings, interpreted psychoanalytically, were used in psychotherapy.

Rorschach (1913a) cites the case of a 40-year-old schizophrenic and feeble-minded house-painter whose interpretations of his own drawings were used to uncover his various complexes. Rorschach elsewhere (1913b) describes the symbolic content of the otherwise meaningless scribbled lines made by a 44-year-old schizophrenic.

Lewis (1925) stresses the therapeutic value of graphic art, pointing out that psychoneurotics are "benefited by this method of objectifying their difficulties." He reports evidence of "collective or archaic unconscious" in the drawings of neurotics and psychotics, and gives examples of "latent contents" which may be obtained from such drawings by the association method. In another paper (1928), Lewis maintains that schizophrenic art productions serve in the important process of objectification and in the socialization of conflicts. He refers to Pfister's conception that an artistic work acts in the solution of the conflict and that its socializing character counteracts introversion and prevents the individual from being "swallowed up by the ego." Ernst (1940) mentions drawing as one of the techniques of communication which the psychotherapist can use with advanced schizophrenics, whose condition is characterized by "dissymbole," manifested in the patient's inability "to formulate his conceptual thoughts upon personal topics or to discriminate the gradations of his emotions in language which is intelligible to others."

In his volume on the psychoanalysis of art, Baudouin (1929) reports a study of art appreciation by free association. Various procedures were used, such as asking the patient to give his associations to a given work of art; or to choose a work which most pleased him from a given group; or to bring in any poem, painting, or musical composition for this purpose. The associations of 9 patients under such conditions are reported in detail. Baudouin concludes that the work of art in each case behaved like (served the function of) a dream, since it was constructed from symbols chosen by the patient and expressed his own complexes. In those cases where the subject was not allowed free choice of the work of art, the contact was less intimate. Among the functions of art, Baudouin mentions: instigation of revery, catharsis, expression and objectification, symbolism and synthesis, and play and "psychological grafting." Stekel (1923) likewise maintains that artistic creation, like psychoanalysis, releases "inner tension" and "unconscious conflicts."

Heyer (1929) calls attention to the "synthetic" value of drawing as a therapeutic device. Elsewhere (Heyer, 1933) he discusses the use of drawing in analytical psychotherapy. Jung (1920) reports the subjective "expressiveness and effectiveness" of the mandala designs made by patients during psychoanalysis. Mention has already been made of the psychoanalytic discussion and experiments on color symbolism reported by Emery (1929). Emery also stresses the emo-

tional appeal and satisfaction derived from color in occupational therapy. In addition to its use in revealing "unconscious symbolism," it frequently arouses the interest of otherwise disinterested patients. Kris (1936) contends that the artistic activities of the insane constitute attempts to readjust to reality, and thus may be said indirectly to have therapeutic value. Wulff (1936) maintains that Kris' theory of the therapeutic significance of insane art should be revised. He holds that the poverty of schizophrenic productions is not the simple outcome of paucity of mental content, but that such productions are the result of "unsuccessful attempts to restore the personality" and as such represent "a compromise formation between the therapeutic striving and the alienation."

In addition to her play technique used in child analysis, described above, Liss (1936) mentions (1) the case of a young male artist with obsessional neurotic symptoms and kleptomaniac tendencies who brought in some of his current sketches and spontaneously interpreted them, and (2) the case of a young woman with no special talent who began sketching, painting, and working with soap and clay and who spontaneously interpreted her products. Wickes (1938) considers drawing as "another way in which images may appear," and reproduces and discusses 79 drawings and paintings, about one-half in color, made during or in the course of psychoanalysis. Data regarding the subject are not given in each case, although some of the subjects were evidently "normal" and others psychotic but not institutionalized. Certain subjects undoubtedly had artistic training. Many of the drawings are imaginative and grotesque. Pickford (1939) points out the therapeutic value of a picture painted impulsively by an artistically untrained male student in his early twenties. Baynes (1940) discusses the extensive drawings made by 2 borderline patients during psychoanalytic treatment. The therapeutic as well as diagnostic rôle of the drawings is emphasized, Baynes maintaining that "with these drawings the patients created their own individual myth through which the self-healing attempt of the psyche was made manifest." Gutheil (1939) also reports the use of drawings in connection with psychoanalytic dream interpretation with neurotic patients.

Mohr, in his manual on therapeutic methods (1925), refers to the clinical use of simple and complex drawings. Vinchon (1926) divides the insane into two classes: (*a*) the hallucinated and deluded who preserve mental integrity, and (*b*) those whose integrity and contact

with reality are lost. The therapeutic effect of drawing is discussed for each of the two types of patients. Vinchon suggests that drawing could serve a sublimative function in the second type, although this is usually not the case since patients with artistic talent are rare and since the drawing itself is often the result of the insanity. Liss (1938) also discusses the therapeutic value of the graphic arts, emphasizing their "cathartic" value as an "emotional release," their use in revealing emotional factors at work in the individual, their function in the abatement of tension and in "making a bridge to reality," and their aesthetic value in providing a common bond or empathy between the individual and the group. Segal (1939) is concerned with the use of art as a test of normality as well as with its application for therapeutic purposes.

In a recent article, "Releasing curative values in the unconscious through the finger tips," James (1939) concludes that satisfactory compensation sometimes results from sketching dream pictures or visual hallucinations or writing down the words of auditory hallucinations. Harms (1939) points out that inasmuch as most mental diseases are unpleasant, whereas art in general is pleasant, the latter should make some helpful therapeutic contribution to the former. In her popular article on "Art and mental health," Kerschbaumer (1939) discusses art instruction in larger mental hospitals as a means of "psychic comfort" and as an important aid in recovery. An example of the therapeutic value of artistic production in the case of the feebleminded is afforded by the work of Ziehen (1904), who reports success in the use of drawings in the education of imbeciles.

On the basis of their extensive work at the Boston State Hospital, Schube and Cowell (1939; in press) report that psychotics undergoing art therapy showed recovery, as measured by their "Restraint-Activity" scale (*cf.* previous section). They maintain, however, that previous art training seems to insulate the patient from the therapeutic influence of a similar branch of art, patients with previous art training showing little improvement in their condition, and in some cases a detriment. At St. Elizabeths Hospital on July 22, 1940, Cowell summarized the Boston work in his talk on "Art productions of the mentally ill and their relation to diagnosis and prognosis." A creative therapy department was initiated at St. Elizabeths Hospital in 1940 by Cowell, who is Director of the National School of Art, Washington, D. C.

At a number of mental hospitals, WPA artists are being employed

to stimulate drawing and painting among the patients as a therapeutic measure. Typical projects of this sort are being carried on at Bellevue Hospital in New York City and at Longview Hospital in Cincinnati, Ohio. The patients work in groups in a special room, are furnished with suitable materials, but are left free to draw what they choose and in their own way. The art teacher is at hand to furnish technical suggestions when requested, and the products are often exhibited where other patients may see them. In a paper presented at the meeting of the American Psychiatric Association in Cincinnati, Ohio, May 24, 1940, De Groot (Anonymous 1940c) cited cases illustrating the rehabilitating effects of artistic productions, and exhibited 50 sketches and paintings made by neurotics and psychotics who had never done artistic work before.

Automatic drawing and writing have also been used by psychoanalysts for therapeutic purposes. Mühl (1930) discusses various modifications of such a technique, and reports case studies in which therapy was achieved by such a procedure. The previously mentioned study by Erickson and Kubie (1938) also demonstrates the rôle of automatic drawing in the relief of pathologic symptoms. Typical "doodling" figures, made during psychoanalysis by a young female patient in a state of acute obsessional depression, were interpreted as disclosing the nature of her conflicts, and were used to effect a therapeutic result. Schultze (1938) reports the substitution of automatic drawing for free association in the case of a schizothymic female neurotic. Interpretation of the symbols proved to be an effective means of therapy.

Many of the papers on *handwriting* discussed in the previous section on diagnosis present therapeutic implications, and need not be repeated here. Thus Schönfeld (1933), for example, states that an intelligent study of pre-school children's "scribblings" will aid in both diagnosis and therapy, and that successful treatment will be reflected in such products.

Several writers have emphasized the therapeutic significance of insane *writings*. As early as 1860, Delepierre (1860) mentioned several asylums where writing was encouraged for its therapeutic value, with good results. Several years later, Raggi (1874) discussed insane writings in relation to prognosis and treatment, contending that not only may suggestions as to the best means of treatment be obtained from an examination of such writings, but the progress of recovery can likewise be indicated in the writings themselves. Hinrichsen (1911) regards poetic creation as a kind of catharsis. He elsewhere (Hin-

richsen 1932) refers to the "release of tension" by artistic productivity, and cites cases of patients as well as eminent writers to support his contention. An example of a recent study in this field is to be found in the paper by Kerschbaumer (1940), who concludes (p. 156) that poetry and prose, as well as drawing, sculpture, and music, are "useful for the patient as a means of emotional expression and relief from tension." Finally, it might be mentioned that institutional journals and similar publications have frequently been used for therapeutic purposes. Andrews (1876) gives an historical account of efforts to use this therapeutic technique prior to 1876, obtaining his data from asylum reports. A discussion of such journals and other writings by the insane will be found in a subsequent article by the writers (Anastasi and Foley 1941b).

In concluding the present section on the therapeutic value of artistic activities in the insane, let us briefly consider the problem of *music therapy.* Only the most representative studies will be reported, and experiments on the effect of music upon breathing and other physiological functions in normals and abnormals will not be considered, since they are irrelevant to our primary interest in artistic behavior. From the earliest historic times, music has been regarded as having therapeutic properties, and examples of such therapy, though interwoven with superstitions, will be found among the early Egyptians, Greeks, Romans, as well as in various forms throughout the Middle Ages. Not only do such conceptions date from remote antiquity, but they are also current among many primitive peoples, intimately tied up with magic, sorcery, and religion.

Among the early Greeks who ascribed medical virtues to music were Thales, Pythagoras, Xenocrates, Theophrastus, Asclepiades, and Celsus. Aretaeus and Galen both used music therapy. In fact most of the early philosophers and physicians expressed opinions on this matter, some of which were doubtless based upon empirical evidence. During the Middle Ages, when "dancing manias" or Tarantism—ascribed to demons or, in Italy, to the bite of the tarantula—were common, music was used throughout Europe as the chief therapeutic agent to hasten the attack and to soothe the subject after the peak of the attack had passed. Celsus maintained that the melancholy insane could be relieved by cymbals and symphonic music, and physicians in various countries have subsequently reiterated this claim. To survey this extensive literature would require space far out of proportion to our present interests. A brief historical survey of much of this literature will be found in the references by Diserens (1926), Diserens and Fine (1939), and Podolsky (1938, 1939).

Podolsky (1933, 1938) gives a brief and semi-popular account of famous instances in which music therapy was used for mental as well as physical ills, beginning with the Early Egyptians, Hebrews, and Greeks. Zenocrates, Sarpander, and Arion used music to curb the outbursts of madmen. Celsus, one of the most illustrious of early Greek doctors, was an enthusiastic exponent of music therapy. Esculapius is said to have cured certain cases of deafness by the sound of the trumpet. Specific instances are also cited of the effects of different kinds of music on physical ills and in arousing emotions in normal persons. Bruckman and Hufeland, about 200 years ago, cured cases of St. Vitus dance with music; Dessarts cured catalepsy. Sneider and Beck used music in treating hysterical and hypochondriacal conditions. In the 17th century, music therapy was widespread; both Philip V of Spain and George II of England were cured of fits of melancholy bordering on insanity by series of special "concerts" arranged for that purpose. At the end of the 19th century, the "Guild of St. Cecilia" and other similar societies organized curative concerts for asylums and other hospitals. Wimmer, in the 1860's, reported many cases of improvement within a group of 1400 insane women following a half-hour piano concert. Examples are also given of the use of music by primitive "medicine men" of many tribes, such as among certain of the American Indians.

Podolsky (1938) states, "Music has emerged as one of the most pleasant of all curative agents. Psychological observations are confirming by measurement what many suspected for a great many years—that music exerts a profound influence on almost every organ in the human body." In his later popular book, "The doctor prescribes music," Podolsky (1939) reports numerous anecdotes regarding the effect of music on behavior, together with a résumé of a few of the experiments in this field. Musical compositions are said to serve as tonics and as sedatives; to alleviate the pain which arises from surgery, severe pain of a non-surgical character, and the milder types of pain; to aid in the digestion of food; to induce sleep; and to "straighten out warped personalities."

Diserens' book, "The influence of music on behavior" (1926), contains a chapter (5, pp. 79–104) on the influence of music on the sick, in which the author surveys the literature from the Early Egyptians and Greeks to 1926, including also modern primitive groups. Opinions regarding music therapy as well as effects in specific cases are cited. Diserens describes many instances of melancholy, mania, convulsions, etc., which have been cured by different types of music. He points

out that specific types of music have been prescribed for particular mental disorders from the Greeks on. Numerous cases are reported from the writings of 19th and early 20th century physicians. The volume concludes with a questionnaire on music therapy submitted to nurses and patients in a hospital; the 15 returns all agreed that music was most beneficial in treating "nervous diseases." The recent book by Diserens and Fine (1939) contains a chapter (6, pp. 145–177) on "Music and medicine," in which musical therapy is discussed, with opinions of classical "authorities" as well as selected experimental results of recent date. The objections voiced by critics of musical therapeutics are cited. Another chapter (7, pp. 181–197) deals with "Music, melancholy and ecstasy," containing a discussion of the melancholic and ecstatic effects of particular compositions, with further emphasis on therapeusis.

In 1729, Richard Browne published his "Medicina musica, or a mechanical essay on the effects of singing, musick, and dancing on human bodies" (1729). Rush, in his "Medical inquiries and observations upon the diseases of the mind" (1812), mentions music as a curative agent in insanity. Laurent (1860), in an historically important paper, discusses the various ways in which music therapy can be employed among the insane, and summarizes the writings of others on the problem. Brierre de Boismont's paper of the same year (1860) describes a visit to the Italian asylum of Aversa, where he witnessed creditable musical performances on piano and guitar by a monomaniac and by an imbecile; he also reports his observations on musical performance and appreciation as effective therapeutic techniques at the Italian asylum of Senavra, in Milan, and at the French asylum of Quatre-Mares. Both of the latter had a patient orchestra and chorus.

Berthier (1864) gives a theoretical discussion of "music and insanity." He emphasizes the physical and emotional effects of music, and cites many instances from the literature on music therapy in physical and mental disorders, since ancient times. Berthier states that music cannot be indiscriminately prescribed, since its effects are not always favorable; different types are needed for manics, melancholics, or monomaniacs, although the last named do not usually benefit much. This form of therapy should be systematically developed, he maintains, and suited to the individual. Chomet (1874) discusses the effects of music in physical and "nervous" illness, and considers the various rules to follow in its use in treatment. Candela Ardid (187–?) cites the views of early physicians, historians, etc., on

the healing powers of music, and discusses its effects on nervous disorders.

Elson (1892) discusses the early history of music therapy, alludes to its use among primitive tribes, and reports that he himself has found it useful in certain physical and mental conditions. He concludes (p. 129), "music has proved of immense benefit to persons suffering from hypochondria or melancholia," but adds that this effect is "counterbalanced by the fact that in some instances music has caused melancholy and madness in auditors." Illustrative cases are cited. Hadden (1896) also sketches examples of music therapy from classical scholars, and concludes, "music is being more and more systematically employed in our lunatic asylums." In his paper presented at the December, 1899, meeting of the Birkenhead Medical Society in England, Dixon (1899) refers to musical therapeutics, briefly outlines its history from the time of Pythagoras, and mentions various affections in which such therapy has proved successful. He divides patients into two types, and considers the kind of music to be applied in each case. Davison (1899) likewise traces the early history of music in medicine. Pastnor (1899), maintaining that three-fourths of all patients are capable of being positively helped by music, argues for its incorporation into the pharmacopaeia of medicine for use in treating both physiological and mental disorders.

Stratton (1901) gives a mentalistic interpretation of musical therapeutics, ascribing such effects to a sympathetic harmony of the individual with the divine "keynote." Wells (1907) reports that Mesmer used strains of soft music, among other things, in producing salutary therapeutic effects in his patients. An extensive treatment of the application of music in treating mental and nervous disorders is to be found in the book by Dupré and Nathan (1911). One chapter (9, pp. 177–181) is devoted to "Mélothérapie," and there is a bibliography on the medico-psychology of music. Rothery (1918) also considers the "therapeutic and preservative potentialities of music." Wilson (1926) likewise suggests that the doctor of the future will make use of music among other agencies.

Vinchon (1913b) gives an historical survey of music therapy in hospitals for the insane prior to 1913, and credits Laurent with originating such work. Demonchy (1912) discusses the influence of different types of music, especially on nervous and impressionable subjects. Paintings showing instances of musico-therapy are reproduced. In his detailed treatment of music and insanity, Rentsch (1926–1927) includes a brief consideration of the influence of music on emotional states and of attempts at music therapy.

Germain (1928) discusses the physiological and psychological effects of music, emphasizing its therapeutic value and citing the results of Toulouse on psychopathic cases. Henssge (1927), after a brief review of the literature on the mental and physiological effects of music, reports qualitative observations on its effect in various syndromes. Thus in depression and psychogenic neurosis, music sometimes gave "relief"; manics usually showed increased excitement; catatonics often showed no change in behavior, although some became "happy" and "less inhibited." Individual differences were observed, as in normal persons. Gutheil (1935) reports cases of psychoanalytic treatment of patients whose day-dreams contained fragments of melodies or song texts. He concludes (p. 431), "experience shows that from a psychoanalytic point of view it pays to investigate the contents, especially when the song shows a compulsion or dream character, and that through this research we can add considerably to our knowledge of the deeper lying psychical mechanisms." Schauder (1939) discusses the general therapeutic value of music in mental illness.

An anonymous article (Anonymous 1930) reprinted from the Medical Journal and Record contains an account of the use of music as a therapeutic device. It is reported that when phonographs are turned on in disturbed wards, patients gradually quiet down and begin to make rhythmic movements. Radios and phonographs, when available, are said to be used almost continuously by patients. Although in quiet wards classical music is more frequently requested, in disturbed wards noisy jazz is said to be required in order to affect the patients. A few patients, however, may be disturbed by the constant sound of the radio or by associations called up by the music. Radio headphones may be used in the case of restless, sleepless patients at night. At the Dunning State Hospital in Illinois, Herschfeld (*cf.* Diserens and Fine 1939: 154) noted the reactions of 2000 mental patients to various classical selections during a piano recital. The concert was part of an experiment to discover the possibilities of music as an aid in the treatment of insanity. Herschfeld is reported to have concluded that "we are on the verge of notable discoveries in musical therapeutics."

Maintaining that participation in various activities will keep the patient's attention away from his troubles, Meese (1930) considers the distracting and dynamogenic effect of music. Animating music is sometimes favorable for apathetic patients. Listening to music is likewise an exercise in concentration, and sometimes arouses a favorable mood on the part of patients who are otherwise unfriendly and

sullen. A dementia praecox patient who spent all day talking about her teeth now listens to music for hours without mentioning teeth. Meese holds that patients do not prefer jazz. Active forms of participation, such as singing or playing an instrument, are better than passive listening. Kalms (1931) reports additional information on music in mental hospitals. He discusses various musical therapeutic and rehabilitative techniques, such as community songs in wards, chorus rehearsals, individual vocal instruction, and musical entertainments, as well as sight-reading classes, choirs, and classes in folk-dancing, music appreciation, and current events in music. Such procedures help to take the patient out of his isolated "dream world," furnish an "emotional outlet," and enable him to concentrate on team work with associates and to develop self-confidence and regain self-control. Older patients are said to prefer hymns and songs which recall the happy past. Men of all ages prefer hymns more than do women. Unfamiliar songs are more effective in the case of younger patients. From studies of auxiliary school children and adolescent psychopathics in Germany, Birber (1931) concludes that such subjects, in common with primitive peoples, prefer very high or low ranges of pitch, shrill dissonances or "dull gloomy combinations." Birber also maintains that music exerts a direct influence on the emotions and drives.

A number of other writers have discussed the therapeutic effects of music in hospitals. Harting (1919) emphasizes its reconstructive value in the case of American soldiers following the World War. Katzoff (1921) discusses music in sanitariums and hospitals, and advocates "medicine through the ears" as an aid to physical and mental health. Harrington (1939) finds that unison group singing is more effective than technical instruction of heterogeneous patients, and that subdued instrumental music, without marked rhythm, produces quiet and repose when played during meals. Harrington also concludes that special training of a group of singing patients helps their powers of concentration. Pierce (1934a) reports that music was found to be a useful therapeutic measure for psychotic patients at a Veteran's Administration Hospital, both when the patients were actively engaged in performance and when they were listeners. Pierce elsewhere (1934b) elaborates upon the active and passive uses of music therapy. He points out that in organizing an orchestra of patients there should be no severe discipline for mistakes in playing; there should be some easy numbers at every rehearsal or concert to avoid strain; practice with an instructor is better than individual instru-

mental practice; and public performances outside enhance the feeling of accomplishment. Richter (1934) reports 3 cases showing the beneficial effect on psychotic patients of participation in the hospital band. In connection with a music adaptability test, Wilder and Stowell (1935) report successful and beneficial band instruction in the case of mentally deficient children.

Van de Wall (1924) considers the utilization of music in prisons and mental hospitals, and reports selected cases illustrating beneficial effects in manic-depressive psychosis, paranoia, epilepsy, etc. In a later article, Van de Wall (1932) maintains that music is a socially educative force in training the mentally deficient. Like Kalms and others, he emphasizes its rôle in promoting organized group life. Since its action and effects are not the same in all cases, individual examinations must be made in each instance. Reports are presented which show the responses of the different grades of the feeble-minded to various types of music. An institutional program is also outlined. Van de Wall and Bond (1934) report the case of a 29-year-old psychoneurotic woman who had suffered from severe pains in the face, neck, throat, abdomen, and legs for many years, without physical cause. In spite of considerable musical training, she was still an "amateur," with bad technical habits, naive aesthetic preferences, and uncontrolled though intense emotional response to music. Therapy consisted in an attempt to direct her emotional interest in music and to bring it under control. The patient was placed in a congenial home with two working women in a metropolitan community with a many-sided music and theatre life, and was given periodic vocal instruction. Muscular relaxation was noted, with the eventual disappearance of all pains. Additional study of poetry as a basis for song interpretation led to a critical and more intelligent attitude toward emotional expression.

Altschuler (1939) describes the routine musical stimulation employed at the Eloise Hospital in Michigan. Patients are exposed to the following types of music: isomoodic (music whose mood is thought to be similar to that of the patient), isotempic (music equated with the patient's "mental tempo"), and isovolumic (music whose general volume corresponds to the degree of emotional tension or outburst characteristically shown by the patient). In a later article, Altschuler (1940) describes a year's experience with group psychotherapy at the same hospital, in which rhythmic drills and listening to music played an important part. Case histories are given to illustrate the positive results achieved.

Several investigators have recently reported data on the effect of music upon epilepsy and related disorders. Alvarez (1937) studied epileptics and normal subjects with reference to the influence of slow and fast music upon frequency, amplitude, rhythm, and form of respiration as measured by a pneumograph. The 29 subjects ranged in age from 10 to 42. It was concluded that the reactions of the epileptic subjects to music were different from those of the normal subjects. Critchley, in his paper on "Musicogenic epilepsy" (1937), describes 11 cases (and reports 8 additional case studies from the literature) of epileptics whose seizures were regularly initiated by listening to music. The age of the first appearance of the attack in these patients was relatively high; the male–female ratio was 10 : 7; and the patients showed a wide range of musical training and appreciation. Although the cases are too rare to permit conclusions regarding clinical features, Critchley tentatively concludes: (1) the association between music and seizure is very close, the seizure only rarely occurring without music, although the latter may be heard without the attack; and (2) in some cases, only certain types of music are followed by attack, whereas in others it may be very general. Critchley discusses the possibility of a conditioned response explanation, which seems especially plausible in those cases in which only a specific tune evokes the attack. Various other explanations, in terms of direct physiological effects of music, are suggested for the more general cases as well as those in which the attack does not always follow music.

The Psychological Approach

The psychological approach to insane art is concerned neither with aesthetic values nor with diagnostic and therapeutic techniques, but rather regards the products as records of artistic behavior. This approach may be characterized by its predominant emphasis upon the perceptual, imaginative, and other intellectual as well as emotional functions leading to the production of such art. The abnormality is studied primarily for the light which it may throw upon the basic mechanisms of behavior. The distortions, disruptions, exaggerations, and retrogressions revealed in the insane products are examined for clues to the nature and development of the functions involved. Interest is thus centered upon an analysis of the behavior itself, in the hope that such a study, carried out on highly selected (abnormal) as well as control (normal) populations, may throw light on the mechanisms involved in imaginative and other forms of creative behavior.

The investigations which could be classified as primarily psychological in their point of view or in the type of data which they furnished have been summarized in some detail in two special articles by the writers, dealing with observational studies of spontaneous productions (Anastasi and Foley 1940b) and with experimental investigations (Anastasi and Foley 1941b), respectively. A description of such studies in the present article would therefore be repetitious. Certain more or less distinct types of investigations can, however, be recognized within the psychological approach, and these will be discussed briefly, with illustrative citation of references.

One group of writers has been primarily interested in the *psychology of art*. Chief among such writers may be mentioned Prinzhorn (1923a), whose extensive collection of spontaneous drawings assembled at Heidelberg was analyzed by him from the point of view of creative activity. Karpov (1926) in Russia was interested in the relationship of psychosis to artistic talent and pointed to certain parallelisms between the manic state and artistic inspiration. The writings of Réja (1907), Vinchon (1924), and Marie (1929) in France were also colored largely by their interest in an understanding of artistic production. Marie (1929: 394), for example, states that "the study of the manifestations of insanity in letters and art clarifies normal art as well as normal general psychology, of which disease is only the psychological dissection." The data on this phase of the problem have been obtained largely through surveys or intensive case studies of patients who drew spontaneously.

An interest in the better understanding of the mechanism of *perception, association, and thought processes* motivated a group of studies whose methodology was more nearly experimental. This work was initiated by Mohr (1906–1907) whose techniques were followed more or less closely by Kürbitz (1912), Sapas (1918), Becker (1934), Pfister (1934), and others. More recently a number of studies on drawing as an index of perceptual disorders have been conducted from the Gestalt point of view. Typical of such studies is the work of Bender (1938) and Schilder (Orenstein and Schilder 1938).

Mention should also be made of the use of *drawing scales* in testing the development and "deterioration" of intelligence. The best known of such scales is the Goodenough test of drawing a man (Goodenough 1926), although similar techniques have been developed by Burt (1921) and Earl (1933) in England, Wintsch (1935) in France, and others. A similar scale based upon children's drawings of a house was developed by Kerr (1937) in England. Drawings are of course

included in certain standardized test series and intelligence scales, such as the Stanford-Binet, and typical disturbances observed in the responses of psychotic and feeble-minded subjects have been reported (*cf., e. g.,* Goodenough 1926, Berrien 1935, Hinrichs 1935).

The use of automatograph techniques and the observation of *automatic drawings,* as in the work of Mühl (1930), and "doodling," as in the recent investigation by Maclay, Guttman, and Mayer-Gross (1938), among normal as well as abnormal subjects may also be included within the psychological approach. The relationships among such motor automatisms in distracted normal persons, the productions by schizophrenic patients, drawings executed under the influence of drugs and other physiological agents such as insulin, and those made in various "trance" states, open up an interesting field of psychological research.

INTERRELATIONSHIPS

Relation to Primitive, Child, "Populistic," and Modern and Fantastic Art

A number of writers have pointed out the resemblances between the artistic products of the abnormal and those of primitive, child, "populistic,"* and modern and fantastic art, as well as particular cultural groups. In fact many of the references previously discussed, especially in the section on the artistic approach, are at least indirectly relevant to the present problem. The reader should also refer to the following section on genius and insanity for additional material on the relation between productions of the insane and those of modern and other schools of art. We are not here concerned with whether the insane can or cannot produce "art," but rather with those studies in which conclusions are drawn in respect to the relationship between the art of the abnormal and that of the other groups mentioned above. We shall first consider typical studies in which *several* of these resemblances have been pointed out by the same writer.

Lombroso (1887, 1895b) was among the first to emphasize the relationship between insane and primitive art; under the latter category he also included Chinese, Japanese, Indian, and Egyptian art. In his discussion of symbolism in insane art, Lombroso describes (1895b: 187) "the mingling of inscriptions and drawings, and, in the latter,

*A term used by the writers in a previous article (Anastasi and Foley 1940a) to characterize the art products of artistically untrained individuals whose primary vocation is in some field other than art; such individuals have been variously termed "modern primitives," "naïve painters," "Sunday painters," and *maîtres populaires de la réalité.*

the abundance of symbols and hieroglyphics. All this closely recalls Japanese and Indian pictures, and the ancient wall-paintings of Egypt, and is due in part to the same cause at work in these—the need in part of helping out speech or picture, each powerless by itself to express a given idea with the requisite energy." Examples are cited, showing mixture of letters, hieroglyphics, and figurative signs. These "rebus-like" symbols are said to be similar to the "phonetico-ideographic" stage through which primitive peoples passed.

Lombroso also emphasizes the atavistic characteristic of such products, maintaining (1895b: 191) that "in the visible manifestations of their thoughts, the insane frequently revert (as also do criminals) to the prehistoric stage of civilization." He elsewhere states (1895b: 199–200), "Both minuteness and symbolism are themselves atavistic phenomena; but, in addition to them, there may be noted (in a large number of cases) a total absence of perspective, while the rest of the execution shows clearly that the author is not wanting in artistic sense." Numerous examples of insane art products are cited, such as works showing disproportionate hands and feet—similar to 13th Century work, Neolithic-like carved bas-reliefs on pipes and vases, etc. The following quotation (1895b: 208) indicates Lombroso's interest in the artistic implications of insane productions:

> "Perhaps the study of these peculiarities of art in the insane, besides showing us a new phase in this mysterious disease, might be useful in aesthetics, or at any rate in art-criticism, by showing that an exaggerated predilection for symbols, and for minuteness of detail (however accurate), the complication of inscriptions, the excessive prominence given to any one color (it is well known that some of our foremost painters are great sinners in this respect), the choice of licentious subjects, and even an exaggerated degree of originality, are points which belong to the pathology of art."

Sollier (1891) described the slow, imitative, and unimaginative drawings of idiots, and pointed out their similarity in lack of perspective to children's and some oriental art.

Kiernan (1892b) also emphasizes the similarity between insane products and those of primitives, children, and certain cultures. In a discussion of symbolism, picture writing, and the fetishistic canons of art, he states (1892b: 245–246), "Commingling of symbols, hence, soon becomes a canon of art, whence it is that Egyptian, Mexican, Phoenician, Chinese, Chaldean, and other early types of art are characterized by the mingling of inscriptions and drawings, and the appearance in the latter of an abundance of symbols and hieroglyphs. There is much evident imitation, undue minuteness and repetition.

These qualities are all detectable in the art of the insane." Kiernan cites examples of imitation in certain insane and imbecile patients who copy the façade of the mental hospital with great skill or delineate the heads of animals with the minute accuracy of primitive man. The insane tendency to ornaments of geometric forms and arabesques, found especially in English-speaking paranoiacs, recalls the arabesques known as "sharks teeth Decorations" in early Anglo-Saxon art. Kiernan agrees with Lombroso that insane art often exhibits, like the Chinese, a tendency to exaggeration of particular details; thus each blade of grass may be distinguished, or the brush strokes may produce the effects of pencil-shading. This characteristic, among others, has recently been noted by Anastasi and Foley (1940a) in the products of "populistic" painters. Kiernan also agrees with Lombroso in concluding that symbolism, arabesque tendencies, minuteness, absence of perspective, obscenity, and color sense deficiency in insane art are evidences of "reversion to primitive art." Symbolism, which is said to be more prominent in the art of the insane than in ancient art, is said to be one of the chief characteristics of the work of children and savages.

Réja (1901) repeatedly points out the resemblance of insane art to that of primitives, children, and prisoners, although certain differences in each case are also indicated. He elsewhere (Réja 1907) contends that in order to understand a complex phenomenon such as art, one should study it in its simple forms. The best approach, therefore, would suggest the study and intercomparison of the work of children, savages, prisoners, and the insane, as well as mediums. Mohr (1906–1907) alludes to the resemblance of insane drawings to those of children, although he points out that many normal adults also draw like children. In a later article, Mohr (1908–1909) suggests that the art of primitives be studied and compared with drawings by mental patients. He also reports psychiatric symptoms in modern art, and mentions a well-known modern artist whose sexual perversion was indicated in his symbolic drawings representing female genitalia in an anatomically impossible and aesthetically repulsive manner. Morgenthaler (1921) describes the case of a 25-year-old schizophrenic whose drawings showed perseveration, automatisms, and other mannerisms characteristic of the ideoplastic nature of primitive art. Certain features of his work were also similar to modern cubism.

Fay (1912) points out that some patients, especially the dementia praecox, spontaneously create colored pictures closely resembling cubism, or reminiscent of certain works of Ensor, Van Gogh, Van

Dongen, Redon, or Rousseau. He adds that the works of some patients, who draw without instruction in drawing, resemble the products of children, with all sorts of crudities and errors. Some of the dementia praecox drawings show serious qualities mixed with gross errors. Fay emphasizes the fact that such patients are deficient in auto-criticism, and draw what they would like to observe rather than what they actually see. Ten illustrations are reproduced, 6 of the works being from the author's collection.

Kürbitz (1912) draws a parallel with children and primitives, citing intellectual realism ("transparent drawings" and confusion of profile and full-face) as examples of basic similarities. He concludes that ideoplastic rather than physioplastic representation is characteristic of insane, children's, and primitive art. Pérez (1917) also discusses the basic similarities in the art products of these three groups, and emphasizes poor and distorted perspective as well as deficient artistic imagination leading to incongruous fantasy or poverty of representation. Hamilton (1918) refers to the same three-way similarity, and states that such products are symbolical rather than realistic. All such art indicates "lowly organized concepts, or those that are the result of a disease" (Hamilton 1918: 485). Hamilton also discusses various forms of impressionism, and divides all cubists and futurists into three classes: the ignorant, the dishonest, and the insane.

Schilder (1918) likewise emphasizes the resemblances of insane, children's, and primitive art, and points out the "symbolic tendency" in such products. In his "Psychopathology," Kempf (1920) reproduces many types of art products, ranging from Classical Greek sculpture to the work of Rodin. There are examples of primitive art, religious paintings, landscapes, mythological subjects, as well as representations of the human figure by various schools of art. Kempf interprets the products psychoanalytically, and holds that "unconscious" trends are represented in the paintings of the great masters as well as those of the insane. A popular account (Anonymous 1921a) of an exhibit of insane art held in 1921 at Frankfurt, under the auspices of the Psychiatric Department of Heidelberg University, classifies the products into several groups: (*a*) those resembling the "expressionist" school, (*b*) those indistinguishable from the works of children, and (*c*) others resembling the work of ancient and extinct civilizations, such as Yucatan, Mexico, Egypt, and Babylon. The writer attributes the similarity between insane art and modern art to the fact that we are living in a mad world "in which forms of grief, impressions of anguish, memories of disillusion, struggle for expression."

In Part 2 of the Introduction to his book, Prinzhorn (1923a) raises the question regarding the distinction, if any, between the products of the insane and those of children and primitive people. He elsewhere (Prinzhorn 1919) broaches the same problem, refers to a possible parallelism between drawings by idiots and children, and concludes that the common principles underlying the art of children, primitives, and the insane should be deduced. On the basis of such principles a simple terminology can be then secured, as well as an adequate description and explanation of the phenomena. In a later article, Prinzhorn (1922) emphasizes avoidance of simple objects, presence of symbolism, abstract rather than realistic nature, schism of content and formal tendencies, poor integration, autism or lack of ulterior purpose, and ambivalent attitude as the major characteristics of insane art. The ambivalent attitude, characteristic of schizophrenics, he maintains, is not present in primitives and children.

Vinchon (1924) refers to exceptional works which are often produced by the simple-minded. Such works are similar to primitive and to folk art, are the result of very unusual circumstances, and are quite rare. Pfister (1923) mentions the resemblance to primitive art of a drawing called "Representation of a suffering soul," made by a male paranoiac. He maintains that regression to a primitive level is characteristic of much insane art as well as of expressionist art in general. Expressionism is said to have arisen as a revolt against the materialism of our society and the current suppression of the "spirit." Pfister objects both to the materialistic, superficial "realism" of the impressionists and to the "autism" of most modern art; it is only expressionism which can reveal "reality-ideals" and "universal spiritual truths." Jung (*cf.* Wilhelm and Jung 1929) points out that the mandala design found among drawings by the insane and psychoanalytic patients is characteristic not only of Eastern art but also of Christianity in the early Middle Ages, as well as such widely differing groups as the Egyptians, Pythagoreans, Indians, Buddhists, and Pueblo Indians.

Rodríguez Lafora (1922) reproduces 37 illustrations of expressionist and cubist pictures and drawings by primitive man, children, and the insane. Many of the insane drawings are cubist abstractions in lines, planes, and streaks of color. Chapter 4 of his later book (1927) is devoted to a psychological study of cubism and expressionism. The chief characteristics of these art forms are said to be: (*a*) autistic tendency to subjective and independent elaboration; (*b*) employment of antithetical forms, such as contrasting colors, direct

and inverted objects, words followed by their antonyms; (*c*) symbolism and obscure insinuations; and (*d*) tendency to stylization. He concludes that all of the above characteristics of modern art are to be found in schizothymic and dementia-praecox patients, the similarity being found in writing as well as drawing. Resemblances are also noted to children's art and to certain types of primitive art. In comparisons with the latter group, Rodríguez Lafora points out that one must discount the skilled drawings of paleolithic man which were affected by two qualities essential to a hunting people, *viz.*, acute visual observation and retentivity, and manual dexterity, which are not characteristic of drawings by neolithic man in the bronze and iron ages.

In her review of studies in the psychology of children's drawings, Goodenough (1928) cites many authors who have argued for and against the relationship between children's products and those of the insane and primitive man. Marie (1929) holds that when an artist is deranged, his attention usually turns towards characteristics of primitive art, such as alterations of perspective, the two eyes seen in a profile, a multiplication of feet to indicate running, etc. The non-artistic insane frequently draw pictures similar to children's drawings and to graffiti. Marie adds that similar tendencies are seen in modern art and in certain older artists such as El Greco and Gauguin. Marie (1931) reports Osario as concluding that many of the insane works in his collection at Iucquiry, Brazil, showed primitive and child characteristics. The drawings made by Nijinsky following the onset of his psychosis, making use of interlocking curves to form highly stylized portrayals, have frequently been compared to primitive (*e. g.*, African) art and to certain schools of modern art. A brief discussion of Nijinsky's works, together with bibliographic citations, will be found in the previous section on The Artistic Approach.

After pointing out that the relation between disease and art was early recognized by Lombroso, Colucci (1931) concludes that many manifestations of modern art, especially the futuristic, show the daring, disorder, and peculiarity of the neuropathic, and can therefore be considered from the neurological viewpoint. The fantasy of the true artist, if it ranges to the neuropathic, may also reach the limit of abstraction; musicians are considered to take first place here, with painters and poets next in order. Modern art, especially the cartoon, is said to have nothing in common with the work of the insane, but rather with that of primitive peoples and children. The latter has

something natural or original about it, Colucci maintains, whereas modern art appears artificial and incomplete, showing the poverty of its manifestations. As a result of his experiment in which schizophrenics were asked to reproduce an object and to copy a visual pattern, Sâto (1933) concludes that primitive drawings, such as are made by children, were found to be common among the schizophrenics, although some on the contrary drew in a normal fashion. A few of the normal control subjects, especially men and women servants and some male attendants, drew as primitively as the schizophrenics. The primitive manner of drawing, however, could not be traced to the education of the subjects, since 3 highly educated schizophrenics produced completely primitive drawings. Sâto feels justified in concluding that primitive drawing is, on the whole, evoked by schizophrenia.

In his discussion of semantic difficulties, Korzybski (1933: 514) calls attention to the close parallels between the drawing and other behavior of the insane and that of primitives and children, and reproduces (p. 515) a drawing by a catatonic patient, taken from Bleuler's "Textbook of psychiatry." Kretschmer (1934) points out the close parallelism among schizophrenic thought or drawing and that of primitives and expressionism. In respect to the former comparison, he states (1934: 101), "There are no important imaginal or affective mechanisms of the kind found amongst primitive peoples which cannot be found extensively in schizophrenics." Among the characteristics mentioned are portrayal of inner feelings rather than external reality, condensation, symbolism, and the tendency to approximate outlines of real objects to geometrical figures and to split up objects into such figures. Ferenczy (1935), after discussing the various attributes of needlework and embroidery among the insane, points out that schizophrenic productions are not only comparable to child and primitive art, but also to folk art. The similarity to folk art is only superficial, however; the two are parallel, with no transition from one to the other. Bürger-Prinz (1932), however, states that schizophrenic drawings differ from those of primitives in that the basic attitude of the former is unique, making empathy and intelligibility impossible. Schizophrenic drawings are also differentiated from those of children and those made during hypnosis. Davidson (1936) also points out the danger of generalizing from superficial resemblances between insane art, child art, 15th Century art, and surrealism.

Maclay, Guttman, and Mayer-Gross (1938) repeatedly point out similarities between doodling and the drawing of children, primitives,

and schizophrenics. Morgenstern (1939) emphasizes the resemblance between the thought and drawings of children and those of primitives, schizophrenics, and neurotics. Contradictory items are placed side by side, and the child's anxiety is said to find a fanciful outlet which is incomprehensible to the uninitiated; he is guided by his affective impulses and by his faith in the omnipotence of his thoughts. Several of the speakers at the three conferences on "Art and psychopathology," held in 1938 at the Harlem Community Art Center, New York City, under the joint supervision of the Psychiatric Division of Bellevue Hospital and the Federal Art Project, W. P. A., referred to resemblances between insane art and that of primitives, children, and modern as well as other artists (*cf.* Anonymous 1938a, b, c, d, e). In his discussion of the Bellevue art work, Garfinkle (1939) describes what he considers to be the type of product characteristic of different syndromes. The schizophrenic patient is said to "paint in symbols" and to "confine himself to a system of diagonals and bisections, triangles, cubes and circles, each having a definite place in the orbit of the patient's delusional system and a special meaning for him." The epileptic "draws like a child in that he draws a tremendous head and an amorphous inadequate body and sometimes fills in the head with many lines that seem to indicate an effort to draw the brain."

Stavenitz (1939), in discussing the implications of the study of insane products for the art critic, states that it is important to understand what the artist is trying to do and why he is doing it. He continues (p. 37):

> "The work of artists such as Picasso, Klee or Kandinsky has very often been confused with or compared to the art of psychotics or children. It is extremely important to recognize the fundamental differences in such cases despite superficial similarities. . . . In order to fully understand any work of art, whether it be the unconscious scribbling of a psychotic or the masterpiece of a great artist, it is necessary to know the individual and social history under which the work was produced. . . . Klee's compositions are of a character seldom if ever encountered in the art of the psychotic, as is also his highly developed wit and subtle sense of humor."

Stavenitz states, however, "Klee has consciously derived his forms and idiom from primitive sources and the art of children." Mosse (1940: 66), in summarizing the results of other investigators, draws the following conclusion, "There is a striking similarity between the paintings of psychotics and the drawings of children and primitives." Mosse interprets this similarity as indicating that such products "have to be looked upon as regressions to earlier stages of mental develop-

ment." Werner (1940) maintains the fundamental similarity of psychotic, primitive, and child imagery as manifested in its "syncretic and diffuse organization." Drawings by the insane, from the collections of Prinzhorn and Kretschmer, are reproduced and discussed as illustrations of psychotic imagery (pp. 152–165).

A few writers have confined themselves to the resemblance of abnormal products to *primitive art.* Thus Kerchensteiner (1905) emphasizes the primitive characteristics of the drawings of the feebleminded, as well as their lack of coherence. Marro (1915) is of the opinion that animism is the fundamental factor in both primitive and paranoiac art. In the paranoiac, he continues, we find a pathological reversion to this primitive level, with deterioration of critical abilities coincident with exaggeration of affective characteristics. The egocentrism of the paranoiac is said to correspond to the anthropocentrism of primitives: both lead to animism. Marro concludes that the grotesque character of much primitive and paranoiac art may be due to: humoristic tendency, tendency to stylization, pathological inspiration, concept of essential character, and visual or motor deficiency.

In his "Psychology of primitive art" (1907, 1917), Verworn contrasts the early "physioplastic" (realistic) character of prehistoric art, based upon sense perception, to its later "ideoplastic" character, the result of abstracting and theorizing. Although insane art is not discussed, children's art is said to be ideoplastic, since their perception lags behind their imaginativeness, as is most of the contemporary art of primitive peoples. Evarts (1918: 365) states that the needlework of the insane is "very primitive, bearing a strange resemblance to the early productions of the race." Delgado (1922) sees in psychopathic drawings and in some doodles an expression of an atavistic and archaic state of mind "loosened" by disease. He states that such products show similarities to hieroglyphics and to the drawings of cave men. Pfister, however, in his abstract of Delgado's article (*cf.* Delgado 1922), feels that the justification for this conclusion is questionable. Szecsi (1935) calls attention to the fundamental similarity between insane and primitive art, and emphasizes the unconscious and intense emotional urge for artistic creation among the insane. Gutiérrez-Noriega (1940) likewise points out the similarity between the drawings of a schizophrenic and those of primitive people.

Lewis (1925) also indicates the resemblance of insane to primitive drawings. He elsewhere (Lewis 1928) compares the artistic attempts of schizophrenics and primitives, contending that the derived content

of schizophrenic drawings, which is said to be a constant feature, is rich in "ancient symbols," and hence offers unlimited opportunities for studies on the "collective unconscious." Freud's "Totem and taboo" (1927), as indicated by its sub-title, is concerned with the "resemblances between the psychic lives of savages and neurotics." He writes (1927: 158), "Only in one field has the omnipotence of thought been retained in our civilization. In art alone it still happens that man, consumed by his wishes, produces something similar to the gratification of these wishes, and this playing, thanks to artistic illusion, calls forth effects as if it were something real. We rightly speak of the magic of art and compare the artist to the magician." The following quotation from Lips (1937: 39–40) illustrates a different answer to the present problem:

"Prinzhorn's attempt to find a parallel between the creative work of the insane and the art of primitive tribes may likewise be considered an interesting experiment, but we need not discuss the seriousness of such a comparison. There has never been the slightest ground for it, unless we again adopt the intellectual standpoint of the 16th century, or that of the art experts under the Hitler regime. I have examined a large number of drawings and models by mentally diseased patients in mental institutions of widely differing types, and only once have I met with any similarity, and then not in the representation, but in the thought of a mental patient as compared with the illogical thinking of primitive tribes, when a professional seamstress, who was a mental patient, made a doll's frock and provided it with a single sleeve, which she sewed on to the frock in front at the breast level. Even if many other details of style and form are reminiscent of primitive art, the creative work of the insane is still the work of diseased persons. But primitive art is the fashioning of a healthy mind. If any comparison at all must be made, it can only be made between the work of the mentally diseased in white and colored nations respectively."

Several writers have dealt only with the resemblance of insane to *children's art*. The features of insane art described by Kiernan in 1892 (*cf.* above) were given by Passy (1891) the previous year as characteristic of the uninfluenced art of school-children. Passy observed a large number of children 3 to 13 years of age who were asked to copy simple objects. Schulze (1912) briefly mentions the relationship of insane to child art, drawing heavily upon the work of Mohr. Bonvicini (1929) discusses the similarity between the spontaneous drawings by aphasic patients with parieto-occipital lesions and children's drawings, and emphasizes the defective and primitive character of each.

White (1930) compares both the language and drawings of psychotics to those of children, pointing out that the drawings of schizo-

phrenics are lacking in synthesis, much like the drawings of the developing child. In a comment on White's paper, Brill (*cf.* White 1930: 716) emphasizes the same similarity, and reports that patients have frequently told him that at certain times they feel a compulsion to poetize in an infantile manner. Especially schizoid-manic types of psychotics resort to these expressions which can usually be traced to some infantile playing with words or to some expressions which appeal to them on account of sound or affective associations. Folly (1933) holds that children's thought, like primitive thought, is preëminently autistic, egocentric, schizoid, and symbolical, rather than logical and realistic. In the poet, the imaginativeness of the child persists.

Kleist (1922–1934) reports that the drawings by cases of "constructive apraxia" show characteristics similar to those found in children's drawings. The elements of a composition may be correctly drawn, but incorrectly arranged in relation to each other, as illustrated by drawing the eyes below the mouth or the hair in the wrong place. Engerth (1933) reports 3 cases of finger-agnosia, 2 of which also showed autotopagnosia, in all of which there were marked disorders of drawing, especially drawings of the face and hands, such that they were markedly similar to children's drawings. Engerth adds that such patients, like children, rely to a great extent upon kinaesthetic and cutaneous sensations and upon symbolization, *i. e.*, by resorting to schemes. Engerth and Urban (1933) describe the case of a 57-year-old plastic artist with sensory aphasia, autotopagnosia, and finger-agnosia. His sculpture and carving during recovery exhibited successive phases which in many ways paralleled the development of artistic behavior in the child. A generally similar result is reported by Gyárfás (1939), who describes the regressive and infantile character of the drawings made by patients when awakening from insulin coma. In the early stages mere scribbling was produced, giving way to successive stages which paralleled in many ways the development of children's drawing.

As a result of extensive work with her visual motor Gestalt test, Bender (1938) reports that adult defectives and psychotics often show primitive sensorimotor drawing patterns characteristic of the various maturational levels of childhood. As an outgrowth of a study on the formation and use of symbols by normal and schizophrenic adults, Cameron (1938) discusses "asyndetic drawing," which is defined (1938: 176) as a "deviation from the conventionally acceptable product in the direction of too little organization." This asyndesis was

found to be characteristic both of the disorganization of thinking encountered among adult schizophrenics and of the thought and drawing of normal children. Cameron states that Luquet refers to this lack of explicit linkage as "synthetic incapacity," and regards it as the result of a fundamental deficiency in children's conceptual organization. Schenk (1939) points out resemblances among the drawings by untrained and untalented adults, children, and aphasics and feebleminded. He stresses particularly their schematic or ideoplastic form, which he regards as an avoidance of the intense attention required for the production of a more realistic or physioplastic representation.

Lastly, there remains a large number of other writers who have been concerned primarily with the resemblance of insane to *modern and other schools of art*. It will be recalled that many of the writers previously discussed in the present section have pointed out such a resemblance, in addition to other similarities. In 1885, Morselli (1885–1894) listed "individualism" as well as "ideographism and symbolism" as the major characteristics of insane art, and in his discussion of individualism pointed out the similarity to what he then described as certain decadent schools of modern art. Although maintaining that insanity alone never results in a product of aesthetic value, Dantas (1900) points out that when there has been former training a product of artistic merit can be obtained, although the ability soon deteriorates. He cites the case of a paranoid patient who produced a gouache resembling traditional Greek sculpture.

Marie and Pailhas (1912, 1913) describe 2 patients who drew extensively. One, a former butcher diagnosed as paranoid with hallucinations and delusions of persecution, showed a "geometromania" in his extensive series of symbolical geometric drawings, accompanied by equally fantastic writings developing his psychological, social, and astrological theories. The other patient, a paranoid with ideas of grandeur, believed himself a great artist and the creator of "conism," a new art contrasted to cubism. This "fetishism of geometry" was best illustrated in his landscapes, in which all forms were reduced to circles, cylinders, and truncated cones, with irradiating lines in blue, green, and red. Künzel (1920) reported the case of a well-known cubist painter who was exempted from military service because of mental abnormality but was finally drafted toward the end of the war. He does not actually claim that cubism is related to insanity, but points out that a representative of cubism whose work hangs in many galleries actually is insane. Since this is an isolated case, he

concludes, time alone will enable us to judge if cubism is a symptom of insanity.

Several of the accounts of exhibits of insane art have referred to resemblances with various schools of modern art. A Current Opinion article (Anonymous 1913) reporting such an exhibit in London in 1913 describes, among others, a cubist drawing composed of squares, as well as several drawings resembling impressionism. A popular account (Anonymous 1921b) appeared in 1921 describing a meeting of a group of 6 psychiatrists with the Art Alliance of Philadelphia to discuss publicly the sanity of the exhibitors in the "extremist" section of the Pennsylvania Academy exhibition. All 6 psychiatrists seemed to concur in the opinion that the art works showed visual defects, a variety of mental disorders, and attempts to evoke unhealthy feelings in a diseased onlooker, and that some cases seemed to be merely an attempt to defraud. Psychiatric examination of 2 of the exhibitors, without the latter's knowledge, led to the same conclusions. Reactions to an exhibit of paintings by psychotics in Paris in 1928 (Anonymous 1928, 1929) indicated relationships to modern irrationalist schools as well as to earlier artists such as Goya and El Greco. The exhibit of "Fantastic Art, Dada, Surrealism" at the Museum of Modern Art in New York City in 1936 contained reproductions of works by the insane for comparative purposes. Attention has already been called to the 1938 Bellevue-Federal Art Project exhibit of psychopathic drawings and paintings, where similar correspondences were pointed out by the conference speakers as well as in the popular press.

Weygandt (1921) draws a parallelism between expressionistic and insane art, and compares 2 modern pictures with 2 insane ones, pointing out their similarities. He lists 13 modern artists who, though not necessarily insane, are described as producing work which "degrades human dignity." Weygandt elsewhere (1923) sketches, with illustrations, the portrayal of morbid characteristics in art from the cave paintings to the present, drawing heavily upon material from various cultures. He discusses in greater detail impressionism, expressionism, cubism, futurism, and extremism. In order to answer the question, "Is this art or insanity?" Weygandt turns to insane art, both to painters who have gone insane and to patients who began to draw after commitment. As a result of his analysis, he lists the following similarities between modern art and insanity: (1) lack of precision, (2) lack of neatness, (3) lightness, (4) bizarre and affected characteristics, (5) monotonous repetition, (6) incomprehensible symbols, understandable only to author, (7) use of extraneous materials,

(8) tendency to stylization, (9) attempt to obtain extraordinary effects by spots, (10) freedom in choice of colors. Weygandt regards modern art as resulting predominantly from "psychic degeneration," and claims that recent circumstances have made us desire "escape from reality," a "quest for novelty," and "disparagement of tradition."

Bychowski (1922) discusses the autistic and regressive character of modern expressionism, cubism, dynamism, and dadaism. They are said to show "artificial regression to the primitives" in their abstract form. Bychowski emphasizes their resemblances to abnormal art in their remoteness from reality, cites scattered French quotations embodying the tenets of various modern art movements, and concludes that such movements are expressions of desperation and of disease. Pfeifer (1923) maintains that whatever seems artistic in insane drawing is the last remnant of sanity, and adds that the trait of expressionism which seems insane is consciously affected,—an expression of refusal which he terms characteristic of the pessimistic world-view of bolshevism.

Janota (1924) states that the works of certain patients closely resemble modern art. He adds that one must be careful in passing harsh criticism on such art tendencies as futurism, cubism, and dadaism, however, since people today class every poor or good idea that is new with the mentally deficient and pronounce it insane. The similarities between insane and modern art are said to be due to the lack of expression of reality; the use of incomprehensible symbols; the artificial division of the subject into different parts; unlimited play—which appears in extreme form in dadaism; and the incoherence of forms presented. There are, however, substantial differences, chief among which is the fact that even the ultra-modernists, in all their confusing divisions, still retain certain academic principles, such as order of composition which, Janota claims, is lacking in the insane material studied by him. Another difference relates to the process of artistic creation, which is more or less "conscious" in the ultra-modern artist and "unconscious" in the insane.

It will be recalled that Hyslop (1911, 1924, 1927) is vehemently opposed to the current tendency to elevate insane art, and warns against the "simulation of disease" by modern artists through imitation of visual defects or restriction of art to the grosser emotions. He (1924: 147–148) states, "in art we find that excessive indulgence in the sensuously beautiful has exhausted the perception of beauty, and in order to arouse some degree of emotion resort is made to the use of abnormal or even painful stimuli. Such individuals become aesthetic

perverts or paraesthetes. The fault is to be found neither in Nature nor in Art; it is in the individual himself who needs rest in order that he may be able to regain the right use of his faculties of appreciation." Futurism in music, as in art, is interpreted as the result of exhaustion, which calls for excessive stimulation; the discordant music of Schonberg is discussed as an illustration. Ruckstull (1925) and others (*e. g.* Anonymous 1911) further elaborate Hyslop's attack upon "post-illusionism and art in the insane." Ruckstull emphasizes the similarity of modern and insane art, all of which he considers to be grotesque, devoid of artistic merit, degenerate, and distinctly pathological. The similarity of the two is taken as a sign of the decadence of modern art. The society for "Sanity in Art, Inc.," founded in Chicago in 1936 (*cf., e. g.,* Anonymous 1940b), has also emphasized the resemblances between insane and modern art.

Prinzhorn *et al.* (1925) maintain that psychiatry receives more from art than it contributes, and add that art products cannot be judged in terms of psychopathological criteria. Lehel (1926) discusses the post-impressionist painters, seeing in their work similarity to primitive art and evidence of schizophrenia. Special attention is given to the works and insanity of "Les Chercheurs"—Van Gogh, Cézanne, and Gauguin. Lehel points out that until the 19th Century, the pathology of art was insignificant, but that insanity in art broke out in all its fury in the 20th Century. In spite of this, Lehel concludes with the statement that he enjoys and has the greatest admiration for this art. According to Stadelman (1927), insane art is not real art because it is the product of a dissociated mind and is itself somewhat dissociated. Its study, however, contributes to the "biology of art," since it enables one to study parts before integration.

Stertz (1927) maintains that schizophrenic drawings, full of mannerisms and rigidity, sometimes bear a superficial resemblance to expressionistic art. Two cases are discussed to illustrate this point. As previously indicated, Stertz agrees with Prinzhorn that schizophrenia does not create artistic values, although he adds that latent talent may be released under such conditions. According to Delacroix (1927: 164), the purpose of certain forms of art is the creation of "a more satisfying, illusory world to replace reality." Some artists, he holds, are able to retain contact with the external world, whereas others become lost in narcissism and pure introversion. It is owing to the latter tendency that frequent comparisons are made between the thought of the artist and that of the mentally sick. Delacroix regards artistic expression as an expression of the "self" midway be-

tween normal thought and insanity, seeking to realize "individual sensibility" in a lyric theme. Such a comparison, however, does not imply that the artist is ill, although "certain aesthetic tendencies find in the schizophrenics an especially favorable soil for their development."

Discussing the "psychiatry of ultraism" (1932), Freedman also mentions the parallel frequently drawn between modern art and insanity. He points out, "the insanity of one age has often been proved to be the genius of its successor," and cites impressionist painting, the music of Wagner, and *fin-de-siècle* literature as examples; thus it is important to consider the interrelationship of cultural and moral values. Freedman also states that pathological determination does not necessarily impair the value of a work of art, and that one must know what was intended by the artist before one analyzes his works. Voluntary symbolism in art is discussed, and references are made to the work of early masters, such as Hieronymus Bosch, as well as to futurism, cubism, and vorticism. Dadaism, or extreme subjectivism, is treated in detail, the factors leading to it are outlined, and it is distinguished from "pathological psychopathy" on the basis of its voluntary and occasional nature.

Fernandes (1933) reproduces drawings by schizophrenics beside those of surrealistic artists, and concludes that both show signs of dissociation, ambivalence, infantilism, loss of contact with reality, and sexual unrest. Mandolini (1933–1934) also holds that the creative mind of the artist is related to pathological minds, although the two are not the same. While the new and creative in art requires a degree of abnormality which is not too far removed from group standards, the paranoid mind is said to be separated from the minds of the group by impermeable barriers. The artist is a leader, while the alienated stands apart. Examples are cited of well-known modern artists, such as Van Gogh, Chagall, Soutine, Genis, and Georg. The following "voluntary distortions" are noted in such works: archaism, or reversion to a primitive mode of painting, as found in Gauguin; infantilism, similar to that found in schizophrenic drawings, illustrated in the work of Henri Rousseau; deformation; and dishumanization, or stylized representation of the human form.

In an address before the New York Branch of the American Psychological Association in April, 1936, Langfeld (1936) described aesthetic activity to be "the best means for the social communication of affective states," just as language and gesture may be said to communicate ideas. Aesthetic activity is closely allied to play activity,

although it has in addition a social reference not possessed by the latter. The artist expresses feelings by means of formal elements, such as lines, colors, or tones, as well as by configurations of such elements. Langfeld adds that definite suppression of any meaning which can be conveyed to others, as in surrealist art, may indicate anti-social and pathological tendencies. Wize (1936) holds that the freedom of "psychic play" in art, especially in modern art, brings it very close to the art of dementia praecox and paranoia. The "magic force of rhyme and rhythm," recognized among the psychotic, is said to reign supreme in art. Baynes (1940) compares the products of borderline schizophrenics with those of Paul Klee; 3 of the latter's paintings and 55 drawings and paintings by schizoid patients are reproduced and analyzed. The contemporary German attitude toward the problem of modern and insane art is illustrated by Schneider (1939) who criticizes the views of Prinzhorn and Lange-Eichbaum and maintains that modern art is degenerate and morbid because it is an attempted imitation of psychotic and primitive art, by more or less degenerate persons of "inferior racial groups."

It will be noted that all of the art works heretofore covered in the present section have been in the fields of drawing and painting, sculpture and other plastic arts, and needlework. We may now consider the relatively few investigators who have pointed out the relationship between the insane and other art groups in the case of *literary productions*. A number of the writers previously discussed have already indicated such resemblances and interrelationships. Dantas (1900) points out that paranoiac writings often resemble the work of minor poets, and cites the presence of neologisms, incoherences, archaisms, symbolism, misuse of capitals and small letters, and italics. He holds that no writing of artistic merit, however, can be obtained without previous training. Stertz (1927) reproduces several pages of poetry written by 2 patients to illustrate his contention regarding the superficial resemblance between insane and expressionistic art. Mette (1928) emphasizes the regressive, archaic, and primitive nature of schizophrenic prose and poetry, as well as its relations to and differences from expressionist art.

Quercy (1920) cites several specimens of poems composed by a 68-year-old patient with delusions of grandeur, who showed great facility in rhyming and meter. Quercy states that the misuse and distortion of words and the presence of neologisms produce an effect somewhat like the work of Gertrude Stein and other modern literary figures. Brill (1931) is concerned with verbal expressions of a rhythmic

nature in the primitive and the insane, and finds similar mechanisms in his mental patients with poetic talent. He claims that all of the latter showed definite "oral erotic fixations," and their neuroses "repressed oral regressions." An examination of the foremost poets, he adds, gives evidence of the existence of distinct "oral erotic manifestations" in their expression. This oral eroticism is also said to be illustrated in the child's repetitive and meaningless sounds, in the adult use of pet-names and "baby talk," in the stereotyped expressions of schizophrenics, in repetition of meaningless syllables in primitive chants, and in the poetry of Gertrude Stein and other writers.

Finally, mention might be made of a few studies in which the resemblance between abnormal and other types of *musical behavior* have been pointed out. Lombroso (1895b: 207) calls attention to the fact that paralytics and others often show a preference for monotonous chanting and states that "in manics, acute and joyous notes predominate, and, still more, the repetition of the rhythm." Lombroso adds that "savages, in speaking, make use of a sort of monotonous chant analogous to our recitative." From her study of auxiliary school children and adolescent psychopathics, Birber (1931) concludes that their attitude toward music is comparable to that of primitive peoples, showing a preference for rhythmical as contrasted with tonic elements, and for dull, high, shrill, or dissonant tones. Felber (1933) discusses the music of infants, neurasthenics and paranoiacs, drunkards, and deaf-mutes, and considers the abnormal's interest in sharp, choppy rhythm, loud noises, and rough racket to indicate a "regression to a primitive level."

The Problem of Genius and Insanity in Art

The current section is concerned with the literature dealing with the relationship between artistic genius and insanity. No attempt will be made to treat the various theories of genius *per se;* for a summary of such theories—classified as pathological, psychoanalytic, typological, and deviational—the reader is referred to Anastasi (1937: 357–362). The present interest is only in artistic genius, as distinguished from genius in scientific or other fields of human endeavor. Much of this literature is theoretical and speculative, while the remainder deals with case studies purporting to show the abnormality of recognized professional artists of varying degrees of eminence and popular acclaim. No attempt will be made to treat the early views on this problem in great detail; for a more extensive consideration and summary from several different points of view, the reader is referred

to Nisbet (1912), Nordau (1896, 1898), Vinchon (1924), Hyslop (1924, 1925), Birnbaum (1920), and especially Lange-Eichbaum (1928, 1932).

A number of early Greek and Roman writers were concerned with the relationship which they believed to exist between genius and insanity. Aristotle noted how often eminent men displayed morbid symptoms of mind, and Plato distinguished two kinds of delirium: one being ordinary insanity, and the other the God-given spiritual exhalation which produces poets, inventors, and prophets. The *furor poeticus* and the *amabilis insania* of the Romans had reference to the same phenomenon. Democritus also saw such a relationship. It was Seneca who inspired Dryden to write his well-known line regarding great wit and madness being near allied. Lamartine spoke of the "*maladie mentale qu'on appelle génie,*" and Pascal pointed out that "*l'extrême esprit est voisin de l'extrême folie.*" A number of other early writers could be mentioned, although these will serve as typical of the early points of view.

As early as 1836, Lélut (1836) scandalized the world of letters by declaring that physiological evidence furnished by the life of Socrates left no doubt but that the "father of philosophy" was subject to trances, attacks of catalepsy, and to false perceptions and hallucinations, constituting what he termed "sensorial or perceptual madness." Ten years later, Lélut (1846) passed a similar judgment upon Pascal, whose visions and hallucinations were of a religious nature. This early work of Lélut served as an important stimulus for the ensuing theoretical work of Winslow, Moreau de Tours, Lombroso, and others, as well as for a host of similar analyses with respect to the abnormal characteristics of other men of genius. In 1849, Winslow (1849, 1852) discussed the eccentricities and insanities of various eminent persons, with special emphasis upon literary genius. Approximately 50 to 60 different authors are considered in the light of their syndromes. He elsewhere (Winslow 1859) discusses the literary productions of the insane, following closely the work of Delepierre (cf. 1860), and cites numerous examples of their prose and poetic work. Under the title, "Mad artists" (1880), Winslow discusses the work of the following artists who were insane: James Barry, Blake, Cellini, Haydon, Landseer, Morland, The Cat Raphael, and Turner.

Fleury, writing under the pseudonym of Champfleury, published his "*Les excentriques*" (Champfleury 1856) in 1856. This book contains biographical anecdotes showing the eccentricity and frequently the insanity of a number of French characters of public life. In his

famous "*La psychologie morbide*," Moreau de Tours (1859) maintains that all genius is a neurosis, and often a psychosis; originality of thought is equally characteristic of all of these conditions. Hereditary factors are emphasized as relating to genius and insanity, Moreau maintaining that most superior individuals have insane persons in their family tree, and *vice versa*. In the last chapter (pp. 518–568), Moreau gives an annotated list of famous persons from all walks of life, including art, classified according to their disorder. The cases are distributed as follows: (1) "properly called insanity"—79 cases, (2) "state of eccentricity"—13 cases, (3) "idiocy and rachitism"—26 cases, (4) "neuroses"—67 cases. Schön (1859) contends that hallucinations and illusions are experienced by creative artists more frequently than by other people, and cites illustrations in the cases of poets, painters, and actors. This is especially true, he adds, in the case of geniuses who have a complete mental image of their product before they begin work, and who consequently simply copy their mental image.

None has espoused the cause of the relationship between genius and insanity more intensively than Lombroso, and none has given more impetus to the pathological view of genius. In his well-known book, "The man of genius" (1895b) as well as in his "Genius and insanity" (1887), Lombroso attributes to the genius certain physical stigmata which are alleged to be indicative of atavistic and degenerative tendencies. He states (1895b: 66), "the resemblance between insanity and genius, although it does not show that these two should be confounded, proves at all events that one does not exclude the other in the same subject." He then cites numerous cases of genius, of which some were artists like Schumann, Tasso, Hoffman, Lamb, Baudelaire, etc., who were insane. Following his lengthy discussion of genius in the insane, Lombroso treats "literary and artistic mattoids" who, having the appearance of genius plus the character of the average man, are alleged to be "semi-insane persons" serving as a link between the madmen of genius, the sane and the insane. Lombroso reports a total of 186 books written by literary mattoids, classified according to subject matter. He states (p. 219), "while poetry prevails among the insane, theology and prophecy predominate in the mattoids, and so on in diminishing proportions for the more absolute, uncertain and incomplete sciences, as we see by the scarcity of the naturalists and mathematicians." Mattoids are said (p. 220) to prefer "the most grotesque and uncertain subjects or questions which it is impossible to solve." Lombroso concludes:

"Not only is there an imperceptible gradation between sane and insane, between madness and mattoids, but also between these last (who are the very negation of genius) and men of real genius." (p. 226.)

"In conclusion, it is very evident that the insane artist is as superior to the mattoid in the practice of his art, as he is inferior to him in practical life; that, in short, in the region of art, the mattoid approaches nearest to the imbecile, and the lunatic to the man of genius." (p. 241.)

In his later "Studies on genius and degeneration," Lombroso (1907) discusses the pathological condition of a number of eminent men, many of them painters and literary figures, and summarizes the writings on insanity and genius by Nordau and others.

Kiernan (1886, 1887) points out that many patients, in the emotional stages of insanity, have composed respectable poetry, and have lost this faculty on recovery. Such analogies, however, are superficial; none of these lunatics was capable of sustained poetic flight. Kiernan lists the following writers who suffered from some form of insanity, although the abnormality marred much of their work, and their creative powers were diminished when their insanity was most fully developed: Nathaniel Lee, Sappho, Lucretius, Marlowe, Ben Johnson, Bunyan, Wycherly, Torquato Tasso, Molière, Swift, Pope, Defoe, Rousseau, Goldsmith, Johnson, Savage, Cowper, Byron, Scott, Coleridge, De Quincy, Rogers, Southey, Shelley, Emerson, Saxe, Poe, Victor Hugo. Kiernan thus differs with Moreau de Tours, Lombroso, and others, and contends that real genius is not the product of a morbid mind; in the exceptional cases where the two co-exist, the genius is evidence of a healthy conservative element struggling with the incubus of disease. The best-balanced poets have been the greatest, he maintains, and cites numerous examples. Kiernan concludes, (1887: 349) "the subtle chain of associating power which constitutes genius in its highest and best sense, differs very decidedly from the disjointed condition existing in paranoia." In a later article on the same problem, Kiernan (1892a) reproduces numerous quotations from early classical and later historical and literary authorities regarding the alleged relationship between genius and neurosis. The theories of various philosophers are also presented, from Plato to Schopenhauer, and the views of Moreau de Tours, Lombroso, Nisbet, Rush, Winslow, Savage, Philomneste, Maudsley, Herbert Spencer, Flourens, and others are treated in detail. After discussing numerous cases of famous persons with mental afflictions, Kiernan concludes, as in his previous articles, that genius is not a neurosis.

Beginning about 1890, Möbius, a German investigator, undertook

a number of detailed case studies of the clinical histories of persons of genius who showed abnormal symptoms. Möbius is best known for having originated the term "pathography." His prolific works serve as a forerunner of the numerous German studies in this field. Typical works are a volume of collected papers (Möbius 1901) containing essays on psychiatry and the history of literature, the study of talent, degeneration, Rousseau, Goethe, etc., and his eight-volume "*Ausgewählte Werke*" (1903–1907), including a discussion of a number of eminent writers such as Rousseau, Goethe, Schopenhauer, and Nietzsche. The historical importance of Möbius' work is attested by Lange-Eichbaum (1932: 104) who states that "it is to him that we owe the fact that psychopathography attained the rank of science in Germany." The general importance of psychopathography in Germany is illustrated by the detailed outline of its problems and methodology found in the report of the "Committee for Psychopathography" by Stern, Baade, and Lipman (1909).

Nisbet's extensive work, "The insanity of genius" (1912), the original London edition of which appeared in 1891, includes an excellent historical summary of the early work of Lélut, Moreau de Tours, Lombroso, and others. Nisbet's own position is indicated by his statement (p. 56), "it is chiefly through insanity that a view can be obtained of the workings of genius, and, from the facts I propose to bring forward, it will be seen that the two conditions of mind have much in common." Genius is considered to be the occasional outcome of inherited nerve-disorder, variously manifested, the right combination of characteristics occurring by chance in one individual. Nisbet cites a number of cases of mental patients whose writings, paintings, or other artistic creations reached levels of which they were incapable while in a normal state. Special attention is given to institutional journals, and to the writings of such literary madmen at Bedlam as Nathaniel Lee, Christopher Smart, and Thomas Lloyd. Geniuses who were insane, such as William Blake, are discussed in detail. Chapter 4 is devoted to examples of "men of letters lapsing into or approaching insanity"; 23 cases are discussed, together with their ancestors, collateral relatives, and descendants. Three of the men—Cowper, Charles Lamb, and Tasso—were actually committed at some time in their lives. Chapter 5 contains a similar consideration of 30 to 40 cases described as "metamorphosis of nerve-disorder, manifested in gout, blindness, deformity, drunkenness, ne'er-do-wellism," etc. Shakespeare is discussed in chapter 6, Nisbet arguing that he came from a weak strain and probably died of paralysis agitans or apoplexy.

In chapter 7, the "musical and artistic faculties allied to insanity" are treated, the cases being classified into eminent musicians (of whom Donizetti and Schumann were institutionalized), plastic and graphic artists, and actors.

In his book, "Degeneration," Nordau (1896) extends the concept of degeneracy, first introduced by Morel and developed by Lombroso, to the field of art and literature; in so doing, he states that he is attempting to fill a void existing in Lombroso's system. He states that he has "undertaken the work of investigating . . . the tendencies of the fashions in art and literature, of proving that they have their source in the degeneracy of their authors, and that the enthusiasm of their admirers is for manifestations of more or less pronounced moral insanity, imbecility, and dementia." Four major types of degeneration are discussed. One is *"fin-de-siècle"*—a feeling or general attitude of imminent perdition and extinction, and a practical emancipation from traditional discipline which is theoretically still in force. The diagnosis is that of degeneracy and hysteria, of which the minor stages are designated as neurasthenia. This type is synonymous with Maudsley's and Bell's "borderland dwellers," Magnan's *"dégénérés supérieurs,"* and Lombroso's "mattoids" and "graphomaniacs." "Impressionists," "stipplers," "mosaists," *"papilloteurs"* or "quiverers," "roaring" colorists, etc., indicate the visual derangements of this group. The fatigue and exhaustion resulting from contemporary civilization, with the increased number of sense impressions and organic reactions, are claimed to be in part accountable for such conditions.

The second type of degeneration discussed by Nordau is mysticism, in which the person imagines he perceives unknown relations. The Pre-Raphaelites, Romanticism, English aestheticism, French symbolism, Tolstoism, and the "Richard Wagner Cult" are among the examples cited. The third type is ego-mania (*Ichsüchtigen*), a salient feature in the character of the degenerate. Idealism, "ego psychology," Parnassians and Diabolists in literature, decadents and aesthetes, Ibsenism, and the philosophy of Nietzsche are discussed in this connection. Realism is the fourth type of degeneracy, examples being found in the "Young-German Plagiarists" and in the emphasis of Zola and his school upon degenerate conditions (*e. g.*, coprolalia, mania blasphematoria); inclination to depict dements, criminals, prostitutes and semi-maniacs; pessimism; predilection for slang, etc. Nordau concludes (p. 536) that in all these tendencies "we detect the same ultimate elements, *viz.*, a brain incapable of normal working, then a feebleness of will, inattention, predominance of emotion, lack

of knowledge, absence of sympathy or interest in the world and humanity, atrophy of the notion of duty and morality." Nordau elsewhere (1898) points out that real genius may not be pathological, but represents a higher evolutionary development. Genius is for this reason said to be more exposed to cerebral disorders, but not to be *a priori* psychotic.

Maudsley (1895: 60) holds that eccentricity "may obviously be of all kinds and degrees from mild and odd to grotesque and silly, running through a scale reaching from actual insanity to the borderland of genius." This is the reason for "the common saying that genius and madness are near akin," but such genius is of an inferior order—intense, narrow, hysterical and explosive; not calm, large, whole and constructive. The common element in genius and madness is held to be a "tendency to variation," a mobile and plastic factor predisposing to new modes of thought. He does not feel that the insane can contribute much to art, for he characterizes (p. 70) such artistic elaborations as "feeble, fanciful, and artificial," and "likely to be nothing better than . . . endeavors to express sentiments that have no substance and thoughts that have no form." He refers to them as "labored contortions of meaningless expression" and as "hysteric art for art's sake."

In his articles on "Intellectual feelings in the mentally diseased," Chizh (1896) points out that the more severe the disease, the more inadequate and feeble the intellectual feelings. Aesthetic feelings weaken first, because they are the most recent and therefore the most unstable acquisition of mankind. Even gifted artists are incapable of producing, in their old age, as fine productions as marked their sounder years. That the genius may suffer from insanity is readily admitted, but the disease destroys, damages, or weakens the development of creative activity. Thus the paradoxical mixing of genius and insanity, of which Lombroso is guilty, is without foundation. Psychiatrists have cited examples of insane patients who occupied themselves in the intellectual field; their interest, however, could only have been pretended, since their limited powers are not in accord with the demands of intellectual labor. In fact their pretended interest was very likely only for the purpose of gaining attention or sustaining their ego. Wizel, in his article on "Wit of the insane with a few words on their artistic ability" (1899), also claims that Lombroso's theory regarding the intellectual affinity of genius and insanity is exaggerated if not false. Insanity always leads to a greater or lesser intellectual impairment, and if humorous or artistic

talent appears in the insane, it does not in the least depend upon an increase of intellectual powers as a direct result of the disease. Lombroso's facts are accurate, but his conclusions are fallacious. Wizel believes that such artistic talent, as well as that for wit, is of two kinds: in one case, the insane carry into the psychotic state a talent previously possessed before the onset of the disease; in the other case, the talent is a new acquisition as a direct result of the disease, although in no case is there a general increase in intelligence, as Lombroso maintained. In the latter case, strong hallucinations, vivid imagery, loss of judgment and of critical and analytical sense may lead to unusual artistic creations. Wizel cites several illustrative cases from the Psychiatric Ward of Warsaw Hospital.

We come now to representative 20th century works on the problem of artistic genius and insanity. Stadelman, in his book on "The place of psychopathology in art" (1908), reviewed by Warstat (1912), assumes a purely statistical definition of abnormality in terms of quantitative deviation from the norm. Artists objectify their world only quantitatively differently from normals, so that the average man curses in anger, whereas Rembrandt produces a dramatic painting, which is just another method of symbolization. From this point of view Stadelman discusses 6 poets and 5 painters, considering their works as subjective expressions. Genius and psychosis are said to be similar in that both result from a physiologically supernormal excitability of the brain as found in fatigue, the only difference being that the genius is capable of synthesizing the "dissociated elements of consciousness." The genius is in danger of psychosis if he loses this synthesizing power. This is held to account for the hallucinations and other abnormalities found in artists. Antheaume and Dromard (1908) discuss the poetry of a number of pathological men of genius, including Baudelaire, Lenau, Musset, Nerval, Poe, Rimbaud, Tasso, Verlaine, and others.

Jacobsen (1909) cites a number of examples from literature and painting which glorify diseased and pathological persons, ranging from cases of malnutrition and pallor to cretins, manics, and patients suffering from all sorts of physical diseases and malformations. Most of the article is concerned with citation of illustrative cases and their diagnosis. De Quincy, Baudelaire, Tasso, and Petrarch are discussed in detail, as are selected portrayals of Christ and other paintings from the Pre-Raphaelites to the present; more than 50 artists are named. Jacobsen argues that the artist who sees beauty in the pathological must himself be mentally pathological. In his later and

extremely popularized book on "Genius," Jacobsen (1926) advances and defends the thesis that genius is the product of neuropathic and "ethnically inharmonious" stock, and that given the "native spark," alcohol and disease act to paralyze inhibitions and so release latent powers. Genius is not associated with degeneracy or insanity; insanity, unlike alcohol and tuberculosis, tends to confuse and to wreck genius. Genius occurs in atypical people who are more likely to develop insanity, but the latter is a handicap to their genius and not the cause of it. Jacobsen cites a large amount of anecdotal case material to support his various contentions. The appendix includes lists of well-known composers and painters who used alcohol, consumptive writers who created literature of high calibre, and similar illustrations.

Hinrichsen (1911), positing a general poetic type, also emphasizes the influence of bodily conditions making for visions and hallucinations. He states that depending on where one draws the line between psychopathology and sanity, all poets and everybody else could be classified as one or the other. In a later article, Hinrichsen (1932) discusses the relations between literary productions and neuroses, with references to well-known writers and to mental patients. He points out, for example, that in the case of a patient of Marcus as well as in the case of Grillparzer's "Ahnfrau" and "Sappho" or Goethe's "Faust," tensions were released by such productivity. The excitement and elation during poetic production, and the "dream state" of "clouded consciousness" are physiological but not necessarily pathological phenomena. Hinrichsen thus concludes that psychic production of great value has nothing to do with neurosis, psychopathy, or psychosis. Bleuler (1911) refers to former artists who became insane, and maintains that their productivity suffers and their works become odd, repetitive, and frequently expressive of their complexes.

Fay (1912) objects to the practice of labeling artists insane by concentrating on their peculiarities; in such cases it is absurd to claim that their insanity was a principal factor in their art. Artists are more exposed to insanity because of their way of living and because of the emotional intensity in creating a work of art. Fay points out that many artists continue to paint after commitment, and some create their best work then, whereas others cease to paint when their faculties weaken. Non-artists often begin to paint when they deteriorate. Fay is skeptical of the value of insane art in understanding pathological conditions, although he maintains that it is easier to detect such characteristics in the work of the trained artist; among the untrained, it is difficult to discover the mental disorders underlying im-

perfections in form, color, and technique. In this connection, he cites well-known modern artists, such as Ensor, Van Gogh, Van Dongen, Redon, and Rousseau, whose technique, in distorted form, is found among the insane. Fay concludes that the insane artist is controlled by his ideas and is deficient in auto-criticism. He draws not what he sees, but what he would like to see; hence the disproportions and distortions.

Vinchon (1913a) refers to the catalogue *"de l'Enfer"* in the National Library, in France. Most of the works in this catalogue date from 1780 to 1810 and illustrate a wide variety of perversions, such as sadism, masochism, fetishism, and sexual inversion. He points out that it is often difficult to distinguish the pathological element, and concludes (p. 158), "Among the insane, obscene writings and drawings are not rare and there one finds no care for art or literature: between these products and certain pages which one considers only as badinage, the steps are numerous and lead imperceptibly from the normal to the pathological state."

In his well-known book, *"L'art et la folie,"* Vinchon (1924) devotes the first chapter to "diagnosis by public opinion." He credits Aristotle with first posing the question of the relation between insanity and genius. Most artists produce works which are quite realistic and portray socially acceptable themes; only a few well-known artists have specialized in highly abstract, symbolical, or erotic forms of art. It is this small group, however, which is puzzling, since it is these forms which are preferred by insane artists, although the latter treat them in a way which is characteristically their own and the drawings bear the stigmata of their insanity. Vinchon emphasizes the fact that the strangeness of a work of art cannot be regarded as evidence of insanity, even if the artist has chosen the same subjects as the insane. One must consider all his works, biographical details, correspondence, opinions of contemporaries, etc. Similarly, the actual insanity of an artist does not necessarily imply that his work is pathological. Van Gogh is cited as such an example, his paintings showing the same stylistic features before and after the "cut-ear" episode and his subsequent admission to the Asile de Saint-Rémy and ultimate suicide.

Vinchon points to the relative rarity of insane art, if one excludes formless and absolutely senseless drawings, as seeming to contradict Lombroso's contention that a number of psychopaths can be considered geniuses. Writers on insane art have repeatedly used the same examples from the collections of Chambard, Sérieux, Marie, and

others, accumulated over many years. The original belief in the relation between insanity and genius was quite generally held by the 18th century encyclopedists and writers on mental medicine and insanity, their views being based upon the citation of incidents in the lives of eminent men. Lombroso's concept of the *dégénérés supérieurs* was the culmination of this point of view. Vinchon states that many painters (*e. g.*, 16th and 17th century Flemish) came from normal and healthy families, and that in the lives of many eminent men pathological characteristics are found only in isolated incidents. Lombroso and others have confused the "wear and tear on the nervous system" among men of genius with genius itself. Fits of depression, excitability, pride, and the like on the part of the artist should not be confused with pathological symptoms, since they may have a very different origin; a sensitive and imaginative person cannot live as calmly as a storekeeper.

In a later article, Vinchon (1927) deals with questions raised by Lehel in his *"Notre art dément"* (1926) regarding whether or not all artists are insane. Lehel points out that patients may begin to draw during institutionalization, but that many ordinary people have done the same thing. Nor are the mystic and erotic symbols which characterize insane drawings any different from those found on the walls of privies. Vinchon comments on Lehel's point of view, and contends that we must distinguish between a sporadic dream and that of a true artist, although Vinchon admits that many eminent artists have been insane. Lehel holds that madness in art broke out in all its fury in the 20th century, when Seurat's "science" produced a number of "isms," to which dadaism has added the finishing touch. Vinchon classifies the 20th century insane, semi-insane, and perverted into the following 5 groups:

"(1) Those under the influence of Cézanne, but without his genius; tormented by a sort of classicism: Derain and Modigliani (the series of his works is the stereotypy of an insane man).

(2) More gifted: Matisse, Roualt, Pascin, Utrillo, Czobel, Kokoschka, Nolde, and Heckel—all possessing ugliness in the extreme. Only a hair's breadth separates these artists from the insane, who devour their works.

(3) The dreamers: Barlach, Kubin, and Gulacsy. They are variants of Redon and Ensor.

(4) The Simultaneists or Cubo-Futurists: Picasso, Braque, Delaunay, Lurçat, Lipchitz, Boccioni, and de Chirico. The Simultaneists are the most numerous, because Picasso has an influence on the new generation almost equal to that of Cézanne. They design two or three figures one on the other. The confusion which results exceeds all the other madness. Picasso conducted experiments with all sorts of caprices. . . .

(5) Chagall, Josephson, Klee, Grosz, Touny—approach the typical insane. They represent the insane by the types and styles borrowed from the insane. They characterize by simultaneism the insane brain which sees the embryo in its mother's stomach and genital organs through her dress and lingerie."

Vinchon concludes that schizophrenia, insanity in general, and artistic passion have evolved simultaneously. The old Hokasai, at the end of his long artistic career, declared himself *"fou de dessin"* and thought so well of it that he signed it after his name. Vinchon adds, however, that the experienced clinician will remain skeptical.

Hamilton (1918: 485) is of the opinion that the symbolic art of children, primitive man, and the insane indicates "lowly organized concepts, or those that are the result of disease." He points out that even in artists whose form is widely accepted (*e. g.*, Goya, William Blake, Whistler, El Greco, Pointellists, etc.), there is an evidence of mental unsoundness. Cubists and futurists are divided into 3 classes: the ignorant, the dishonest, and the insane. Hamilton treats in detail the psychoses of El Greco, Blake, and Wiertz (*cf.* Anastasi and Foley 1940b, section on architecture). The pre- and post-institutional work of Charles Méryon is also discussed and illustrated, Méryon having been committed at Charenton in 1858. Müller-Freienfels (1921) makes the unconditioned statement that the "basic difference between poetic talent and average humanity" is the increased emotionality of the former. Hildebrandt (1920) devotes the sixth chapter of his book to "genius and degeneration," in which he maintains that the overexcited moods of psychotics and the hallucinations of delirious persons can be used for poetic and artistic purposes. But such a productive force, he argues, does not originate in the disease; it is only preserved and colored by it.

Pfister (1923) reports a psychoanalysis of a young French artist "acknowledged in his own circle as a highly gifted artist." Free association was used in connection with dream and drawing analysis. The drawings, including 3 portraits of the analyst, a self-portrait, a portrait of the artist's wife, as well as several "symbolical" and abstract subjects, are interpreted psychoanalytically in terms of their manifest and latent content. The paintings are said to reflect a change in the artist's emotional attitude: the earlier ones are expressionistic and reveal his hatred of mankind together with references to unpleasant early experiences; the later ones show him in a more lyrical mood and at peace with the world. In his *"Psychoanalyse de l'art,"* Baudouin (1929) summarizes Pfister's conclusions based upon the above case. Baudouin emphasizes the fact that such paintings

are expressions of "disguised complexes" and are often attached to recent experiences which have reawakened the "complex" by association and have become combined with it, after a brief incubation period, to produce the work. Such paintings thus play a part in the sublimation, over and above the analysis itself. In such a manner, Pfister's artist patient, who had risked falling into a pathological "autism," regained a means of communication with men and reality. Baudouin adds that he has made a similar analysis of an eminent poet, Henri Mugnier, born in 1890. Baudouin (1924) elsewhere gives an objective and straight-forward explanation of many psychoanalytic terms, pointing out, for example, that symbolism should not be regarded as fixed and immutable, but as developed through individual experience. Baudouin states (p. 295) that those poems which are regarded as masterpieces "are the outcome of a very strong and very precise condensation of images" which "would seem to favor the genesis of great works." The symbol is the essential means of expression in poetry, as in all imaginative work.

Stekel (1923) voices the psychoanalytic view regarding the fundamental psychological similarity between the dream, artistic activity, and neurosis, in so far as all are said to "draw upon the unconscious." He considers the relation between artist and neurotic to be very close, and maintains that "not every neurotic is an artist," although "every artist is a neurotic." He states that there are no absolutely normal persons. "In everyone's breast there slumbers a bit of neurosis," and this is held to constitute the foundation of all creative ability. "All creative ability represents a freeing of excessive energies, an outflow of pressing inhibitions;" this is held to be especially true in poetry, so that "every poetic creation is a confession!" Stekel objects to the connotation that genius is degenerate. He distinguishes between neurosis and psychosis, and maintains that neurosis is not a taint, but "forges the background for all progress." Similar psychoanalytic views with respect to the creative value of neurosis have been repeatedly expressed by Lewis, Schilder, and others.

Weygandt (1924, 1925) warns against the lack of objectivity in the field of insane art, and criticizes Prinzhorn, Jaspers, Schilder, and others for "heroization" of their cases. Weygandt outlines four possible relationships between insanity and art: insanity may (1) extinguish artistic ability (*e. g.*, Makart), (2) run parallel with it (*e. g.*, Manet), (3) facilitate dormant talent, (4) cause change in style (*e. g.*, Van Gogh, and Weygandt's own case of a girl illustrator of children's

fairy tales who changed the characteristics of her drawings and ended up by making cloth dolls). Audry (1924) is interested exclusively in insanity among professional artists. He cites a number of illustrative cases, and emphasizes the difficulty of generalization. Toulouse-Lautrec and Jongkind are given as examples of artists who do not show their aberration in their work, but whose work either ceases or remains unaltered during their illness and appears perfectly normal. A second major class contains artists who are normal but who paint pictures which would be diagnosed as abnormal; Jerome Boch, Breughel the Elder, El Greco, and Goya are members of this group. Thirdly, there are those insane artists who give indication of their disorder in their work, of which Van Gogh, A. Guirand, Monticelli, William Blake, and Méryon are outstanding examples. Henry (1925: 157–159) discusses 25 cases of eminent men who have commonly been regarded as normal but who were definitely abnormal. Among the different artists mentioned are: Balzac, Beethoven, Byron, Chopin, de Quincey, Goethe, Mozart, Nietzsche, Pascal, Rossini, Rousseau, Schiller, Schopenhaeur, Socrates, Swift, Tasso, Tolstoy, Voltaire, Wagner.

Hyslop's extremely conservative attitude toward modern art, discussed in the previous section, is carried over to the artists associated with "extravagances" in art, music, and literature. In "The borderland" (1924), he emphasizes the fact that such individuals are either suffering from disease or are attempting to achieve self-advertising and short-cuts to notoriety. Schönberg's discordant music is discussed at length, and futurism in music, as in art, literature, science, and religion, is interpreted as the result of exhaustion, making excessive stimulation necessary for a satisfactory response. He maintains (p. 136) that "true insanity occurred in Romney, Cosway, Haydon, and Landseer." Turner was probably insane, as were James Barry and William Blake. Hyslop continues (pp. 136–137):

"Many of the greatest painters, sculptors, and engravers, whose names live in their works, have their names inscribed in the case-books of our asylums. The chronicles of Bedlam alone would provide enough material to form a substantial volume. For obvious reasons, however, such chronicles are sealed. Giorgione, Tintoretto, Paul Veronese, Botticelli, Leonardo da Vinci, Raphael, Albert Dürer, Claude Lorraine, Salvator Rosa, Benvenuto Cellini, Vandyck, and Watteau, all suffered from some form of nervous disease. Among artists we have only to mention Sir Joshua Reynolds, Flaxman, Morland, Fuseli, Lawrence, Liversedge, Wilkie, Mackie, Doré, and Meissonier, all of whom had distinct evidences of degeneracy.

"We are told that Molière, Petrarch, Charles V, Handel, St. Paul, and Peter the Great were epileptics. Paganini, Mozart, Schiller, Alfieri, Pascal, Richelieu, Newton, and Swift were victims of diseases epileptoid in character. Dr. Johnson, Napoleon, and Socrates suffered from spasmodic and choreic movements. Zeno, Cleanthes, Lucan, Chatterton, Blount, Haydon, and Clive committed suicide. Coleridge, Sheridan, Steele, Addison, Hoffmann, Charles Lamb, Burns, Morland, Turner, Dussek, Handel, Gluck, and others abused the use of alcohol and other drugs. Salhurst, Seneca, and Bacon were suspected felons. Rousseau, Byron, and Caresa were grossly immoral. Dayner, Clement, Diderot, and Prayn were perverts, etc. Shelley, Bunyan, Swedenborg, and others had hallucinations."

In his well-known book, "The great abnormals," Hyslop (1925) discusses eminent men in all walks of life who were abnormal in one way or another. Chapters 10 and 11 are devoted to "The peculiarities of men of genius," a total of 111 of such men—mostly from the various fields of art—being discussed. This book ranks with those of Nisbet, Birnbaum, and Lange-Eichbaum as the most comprehensive treatments of the abnormalities of men of genius. In his "Mental handicaps in art," Hyslop (1927) devotes chapter 4 to "Disease in art" and chapter 5 to "The influence of toxins." He states (p. 68), "degenerates often turn their unhealthy impulses towards art, and not only do they sometimes attain an extraordinary degree of prominence, but they may also be followed by enthusiastic admirers who herald them as creators of new eras in art." He points out (p. 69), "the artistic efforts of mental patients, however, do not always bear evidence of degeneration. The ideas of the paranoiac (or deluded) may be grotesque and fanciful, but the artistic merit may be great." The insanity of Baudelaire, Gautier, and William Blake is discussed in connection with the "symbolism of the insane." Hyslop also voices the opinion that "stigmata of degeneracy" are not confined to artists alone, but are also found in well-known art critics. Birnbaum (1920) likewise reports a collection of all possible forms of abnormal manifestations from the biographies of eminent persons, primarily artists. Approximately 150 names are discussed.

Prinzhorn (Prinzhorn, Gesemann, Kronfeld, and Sach 1925) points out that belief in the relationship between poetic imagination and insane dreams and hallucinations was common in ancient Greece and Rome. Lombroso's views are discussed at length, as are those of Kretschmer, Birnbaum, Pfeifer, Morgenthaler, Jaspers, Kronfeld, Sachs, and Jaensch. Karpov (1926) subscribes to the theory that man has not yet concluded his cycle of development, and that in this path of development certain individuals, *viz.*, those subject to insanity,

far outstrip the rest of mankind. All of the insane do not lapse into mental chaos; some of them, especially the cyclothymics, produce great works. Almost all of the greatest creators in the arts show some sign of this particular disease, as is evident from their biographies. Karpov's view regarding the creative ability of the insane is best summarized by the following conclusion (p. 190), "Our researches indicate that a man with an unbalanced nervous system can possess great artistic talent and that men whom one considers balanced cannot produce great works in a single scientific field; they can only realize and propagate the great works of the 'abnormal'."

A series of works by Cabanès (*e. g.*, 1895–1900, 1920, 1924, 1930–1935, 1938) are concerned with the general problem of genius and insanity. In his 4 volumes on "*Le cabinet secret de l'histoire, entr'ouvert par un médecin*" (1895–1900), he is concerned with a study of the kings and pretenders to the French throne from a pathological viewpoint, as well as with the maladies of notorious artists and other personages. The psychopathological interpretation of history, its clinical value, and the relationship between medicine and sociology and philosophy are treated in another work (Cabanès 1920). Cabanès questions the concept of "*dégénérés supérieurs*" in favor of that of "*desharmoniques.*" A 6 volume work on "*Les indiscrétions de l'histoire*" (Cabanès 1924) deals with medico-historical problems, many of which center around the abnormality of eminent artists and other historical figures. The insanity of selected French artists also forms the subject matter of two later works (1930–1935, 1938), the former on "*Grands névropathes, malades immortels*" containing material on the following: Baudelaire, Byron, Chateaubriand, Molière, Pascal, Shelley, Wagner (vol. 1); La Fontaine, Rousseau, Rétif de la Bretonne, Bernardin de Saint-Pierre, Lamennais, Comte, Alfred de Musset, Victor Hugo, Sainte-Beuve, Les Frères de Goncourt (vol. 2); Hoffmann, Swift, de Quincey, Coleridge, Cooper, Tennyson, Heine, Chopin, Gogol, Gontcharov, Lermontov, and Dostoïevsky (vol. 3).

The well-known book by Jaspers (1926) compares Strindberg and Swedenborg with Hölderlin and van Gogh. Case studies reveal that all four were schizophrenic, Jaspers maintains, although only the last two reached the chaotic stage. In this connection, mention might be made of the paper by Hedenberg (1938), containing a critical review of much of the extensive literature concerning van Gogh's illness and art. Hedenberg concludes with Evensen that van Gogh suffered from epilepsy. The general relationship between schizophrenia and giftedness is discussed by Tsubina (1929).

Rentsch (1926–1927: 37–55) devotes half of his paper to the citation of a long list of composers who suffered from various forms of insanity. Schumann showed symptoms of dementia praecox and had pronounced auditory hallucinations; Hugo Wolff was a paralytic; Smetana had auditory hallucinations and paralysis; and Beethoven was a manic-depressive whose works are expressive of his sufferings. Fifty names of insane musicians are cited from a list given by Blaschke (1909). Rentsch concludes that insanity usually causes either a deterioration or complete cessation of musical activity, and that it is impossible to point out characteristic deviations in the works of psychopathic composers.

Rodríguez Lafora (1927) refers to a number of psychoanalytic studies of poetic and other forms of artistic creation. Studies of eminent artists are cited, as well as studies of typical insane patients. He contends that poetic inspiration has much in common with psychological acts of "subconscious origin," such as dreams, mystic ecstacy, visions and hypnagogic hallucinations, and periods of vivid imagination initiated by drugs, alcoholic intoxication, or fever. The latter agents, however, will not produce artistic inspiration in a common person any more than will insanity. Insanity may bring out a work of genuine artistic merit in an individual with talent. Rodríguez Lafora concludes that although pathological artistic inspiration helps in understanding normal activity since it is merely an exaggeration of the latter, nevertheless the psychological and aesthetic problems with respect to the artist are entirely distinct. Originators of modern art movements have proceeded with a gradually evolving idea in view, although some of their followers who derive satisfaction from such autistic art may well be schizophrenics.

The relationship between language peculiarities of schizophrenics and the writings of well-known artists is close, according to Mette (1928). He refers to Prinzhorn, Schilder, Reiss, Storch, and Kretschmer, and cites Bleuler's statement that a schizoid disposition is a necessary condition for artistic talent, Jaspers' view that psychosis releases latent creative powers, and Pfeifer's emphasis upon the resulting lack of former inhibitions. Mette points out that one fact seems well established, *viz.*, that in early schizophrenia one frequently finds artistic talent not previously present, and that such schizophrenic creations surpass in number and quality those of other psychoses. Mette discusses selected examples of schizophrenic prose and poetry, one case being that of Hölderlin at the beginning of his psychosis.

Mette concludes that it cannot be decided whether or not psychosis creates talent, although it certainly creates particular forms of expression (*e. g.*, in the schizothyme poet) which are also found in true art. Many poets prefer schizoid characters in their works. The main difference between expressionism and schizophrenia seems to be that schizophrenics only desire to satisfy their craving to express themselves whereas the expressionist is attempting to produce a certain effect on a reader.

Perhaps the single most scholarly work on the problem of genius and insanity is Lange-Eichbaum's *"Genie, Irrsinn und Ruhm"* (1928). After an extensive discussion of his theory of genius, Lange-Eichbaum cites (pp. 350–432) the biographies of 200 men and women of genius from all countries, periods, and fields of endeavor, showing their abnormalities. The biographies are fully documented, and vary in length from several pages to the simplest comment "for a long time psychotic." There is a bibliography of 1652 references, classified under 21 headings, each dealing with a different aspect of the problem. In his later book, "The problem of genius," Lange-Eichbaum (1932) presents a condensed version of his general point of view. The chapters deal with genius as related to value, fame, talent, insanity, and civilization, respectively. After showing (p. 11) that "genius cannot be anything absolute," but implies a valuation, he considers the following 4 factors in the valuation of genius: the enjoyment factor, the "ego-positive," the consumer, and the bearer. He also points out (p. 30), "genius is a relationship," and reproduces "fame curves" (extent of recognition as a function of time) for Goethe, Hölderlin, Shakespeare, Grünewald, and Walther von der Vogelweide. Genius is not talent; "no psychologist ever will be able to describe a specific form of talent as essential to genius" (p. 97).

After citing the early work of Lélut, Moreau de Tours, Lombroso, and Möbius on the problem of genius and insanity, Lange-Eichbaum states:

"There is not an invariable or necessary association of genius with insanity. None the less, the detailed psychiatric investigations of the last hundred years show with irrefutable cogency that among geniuses healthy persons form a small minority. Most of them suffer from unfavourable abnormalities, deviations of one sort or another, which are bionegative in their working. Thus, the simplest answer to the question, what is the relationship between genius and insanity, would be a numerical one, showing the much greater frequency of mental disorder than of sanity among geniuses." (p. 110)

"When we study the entire population of the country with reference to the existence of mental disorders, we find that from 0.2 to 0.3% are under restraint

in asylums, and that, at a fairly high estimate, not more than about 0.5% of the total population will be affected with grave mental disorder. But among geniuses (considered to the number of three or four hundred individuals) we find that from 12 to 13% have been psychotic at least once during their lifetime. Confining our examination to the 'very greatest' names, numbering seventy-eight in all, we find that more than 10% have been psychotic once during their lifetime; that more than 83% have been markedly psychopathic; that more than 10% have been slightly psychopathic; and that about 6.5% have been healthy. The proportion of diseased persons becomes a little greater still, if we select thirty-five persons who are regarded as 'the greatest geniuses of all': the psychotics number 40%; the psychopathics more than 90%; the healthy 8.5%." (p. 112)

Lange-Eichbaum maintains, however, that "the following statements can be regarded as firmly established:

1. Most geniuses have never been psychotic, but psychopathic.
2. Very many of them, as psychopaths, have suffered from inward cleavage, from nervous tension; or they have been neurotic.
3. Many of them also, as psychopaths, have been given to drink or drug-habits, and have exhibited fleeting and transient inclinations towards psychosis.
4. Many of them, likewise upon a psychopathic basis, have manifested certain exceptional mental states to a very extreme degree: depravity, absent-mindedness, fancied wonderful happiness, a craze for creation, ecstasy, a preposterous conviction of inspiration, a crisis of conversion, etc. Such conditions have in many cases been wrongly classed as manifestations of declared insanity.
5. In cases where there has been genuine psychosis, we by no means always find that there has been any causal connection between the psychotic disturbance and the creative activity; and often enough there has not even been a temporal coincidence." (pp. 115–116)

He then proceeds to group some of the best recognized geniuses in classes according to their type of mental disorder, beginning (p. 116) with "those who suffered from genuine psychosis." The effect of the disorder on the individual's work is pointed out.

"Fame" is held to form the link between "genius" and "insanity," Lange-Eichbaum concluding (p. 139) that on "at least three levels on the ladder of fame we find statistical evidence of the causal efficacy of morbid factors frequently influencing the relationship between the individual as he actually existed and his achievement, between achievement and fame, and finally between fame and the harmony of genius." He continues:

"Almost everywhere, and especially in the subjective fields of imaginative writing, religion, and music, gifted 'insanity' gains the victory over simple, healthy talent. The psycho-pathological is an excellent pacemaker for talent. This does not signify that genius is itself 'insane,' but that the mentally disordered person is more likely than the sane person to become famous, and that the fame of the mentally disordered person more often than the fame of the mentally healthy person leads to elevation to the rank of genius." (p. 40)

In the final chapter, on "Genius and civilization," Lange-Eichbaum demonstrates diagrammatically (p. 144) the various interrelationships between the four magnitudes of talent, fame, veneration for genius, and insanity. Intersecting lines divide the total area into 12 "fields," comprising: 4 groups of genius, 4 of merely famous persons, and 4 of ordinary persons. There are 4 "abnormal" groups, as follows:

(a) "psychopaths with exceptional gifts" (Group 3)

(b) "psychotic or markedly psychopathic persons devoid of exceptional talent but revered as saints or geniuses." (Group 4)

(c) "highly gifted psychopaths who have not yet or never will become famous (the road being barred for them in many cases by some particular characteristics of their psychopathy, for instance by extreme infirmity of will)." (Group 11)

(d) "untalented persons who suffer from mild or severe mental disorder." (Group 12)

Examples of each of the 12 groups are cited in the discussion.

The conclusions of Lange-Eichbaum and others in the field of psychopathography are defended by Kloos (1931), who contends that determining the disease of an author does not diminish the cultural value of his work. Kloos emphasizes the need for an impartial investigation of the psychological, biological, and social factors, and the need for the investigator to free himself from "hidden affective tendencies." In his article in Bumke's "*Handbuch*" (1932), Bürger-Prinz (1932) voices the opinion that although the mentally diseased has many new experiences, he typically shows a lack of ability to express them; only real artists like Hölderlin and van Gogh can produce anything creative during acute psychosis. Bürger-Prinz discusses in detail the writings of the eminent schizophrenic writer, Julius Langbehn, whose voluminous, aggressive, and obscene works were influenced by Rembrandt. Willard (1929) gives a brief account, without references, of insanity, alcoholism, criminality, immorality, and similar traits among a number of famous persons in history. A large number of these persons were writers, painters, and musicians who were definitely pathological, the following having been committed or judged as insane by a physician: Ben Johnson, Swift, Shelley, Cowper, Southey, Schubert, Schumann, Poe, Richelieu, and Tacitus.

Freedman (1932) emphasizes cultural and evaluative factors, pointing out, "the insanity of one age has often proved to be the genius of its successor," as is illustrated by impressionist painting, the music of Wagner, and *fin-de-siècle* literature. Pathological determination, he maintains, does not necessarily impair the value of a work of art. We must know what was intended by the artist before we can analyze

his works. The work of Bosch and of the various schools of modern art, especially dadaism, is discussed in this light. Del Greco (1935) considers various writings and intellectual works from which some diagnosticians tend to infer the insanity or psychodegeneration of the writers. He describes the method to be used for arriving, if possible, at a true diagnosis and the difficulties to be met if one does not wish to obtain results of little or no importance. The individual who writes very fantastic and weird tales may be normal in his social relations and in the practical activities of everyday life. In a much earlier work (1898), Del Greco discusses the insane and criminals in a number of famous literary masterpieces, and argues that their authors were similarly disordered. Eliasberg (1935) interprets the artistic drawings made by an 11-year-old boy while in a Jacksonian seizure as due to the lack of normal inhibition at such a time. He concludes that such cases seem to prove that the theories of the chronic exceptional state as a being *sui generis* and those of the actual inspirational state contain some measure of truth.

Wize (1936) maintains that in language and science as well as in art, morals, and religion, psychopaths and schizophrenics sometimes develop ideas which are comparable to those of the genius in these fields. In fact, great poets and artists are frequently psychopathic. Various examples are cited to show the similarity between beliefs and statements of the insane and those of great intellectuals. Evenson (1936) emphasizes the need for investigation of the works of the schizophrenic artist before, during, and if possible after the onset of his psychosis. It is suggested that such a thorough study of two Swedish artists, Ernest Josephson and Hill, be undertaken in a manner similar to that previously used by Evenson in the case of the Norwegian painter Hertervik and reported at the Helsingfors meeting of the Congress of Scandinavian Psychiatrists. Cazzamalli (1937) lists examples of visual and auditory hallucinations which have influenced and guided the thought of poets, dramatists, painters, musicians, scholars, inventors, statesmen, and philosophers. A discussion of the resemblance between artistic genius and insanity from a strongly psychoanalytic point of view, is to be found in a recent paper by Levey (1940).

Space will not permit a discussion of the literature dealing with *case studies* of individual eminent artists who displayed abnormal symptoms at some time in their lives. Such a bibliography alone would include several thousand references. For material and references on this problem, the reader is again referred to the general sources men-

tioned in the opening paragraph of the present section, and especially to the work of Lange-Eichbaum (1928).

Personality Traits and Artistic Ability

In the present section we shall consider studies on the correlation between personality traits or disorders and artistic ability. No effort has been made to survey all of the scattered literature on this subject; only representative studies directly relevant to the problem will be mentioned. Carroll (1932) reported an experiment in which University of Minnesota students were given the Meier-Seashore and McAdory art tests, the Bernreuter Personality Inventory, and the Bathurst Diagnostic Temperament Test (introversion-extroversion). The following correlations were obtained:

Bathurst and Meier-Seashore	$r = -.18 \pm .070$	$(N = 79)$
Bathurst and McAdory	$r = -.11 \pm .070$	$(N = 87)$
Bernreuter 1N (neurotic tendency) and Meier-Seashore	$r = .08 \pm .045$	$(N = 218)$
Bernreuter 4D (dominance-submission) and Meier-Seashore	$r = .05 \pm .045$	$(N = 218)$

Comparing the 10 highest and 10 lowest subjects on the Meier-Seashore gave no reliable difference on the B-1N or B-4D. In the light of the low correlations, Carroll concludes that the study lends no support to the current dogma that talent in art tends to be associated with personality disorders.

In a report on "The measurement of artistic abilities" prepared for the Carnegie Corporation, Kinter (1933) describes a study conducted by The Psychological Corporation in which Bernreuter blanks were filled out by 21 successful artists, a small percentage of those circularized. Average percentile scores in emotional instability (neurotic tendency), self-sufficiency, introversion-extroversion, and dominance-submission were all close to 50, the one in emotional stability being 57.0. The range within the group was very wide. Kinter concludes (p. 44), "the group is too small to warrant final conclusions, but the evidence tends to show that artists are not temperamentally unlike non-artistic persons, in spite of the contrary tradition. They differ among themselves more than they differ from unselected groups of people." In a recent experiment by Sisson and Sisson (1940), college students of the highest (introverts) and lowest (extroverts) scoring levels on the third scale of the Bernreuter (B-3I) were given tests for attitudes toward music and poetry and a question-

naire designed to measure interest and training in art. Scores on the "aesthetic" scale of the Allport-Vernon Study of Values were also obtained. Little difference between the two original Bernreuter groups appeared in attitudes toward music, or in responses to the questionnaire, although the introverts made a higher average aesthetic score on the Allport-Vernon than the extroverts.

Farnsworth (1935) reports data collected to check the common belief that musicality is related to abnormality. Schoolchildren in the lower grades were rated on a 5-point scale for degree of effort, adjustment to the teacher, adjustment to classmates, extent of dextrality, and normality of speech (3-point rating). Coefficients of contingency and critical ratios showed a tendency for those rated "good" in music to be given somewhat better than average ratings in other traits and to be normal in speech and handedness. In a follow-up study by the same investigator (Farnsworth 1938), teachers rated children on a 5-point scale for musical ability, drawing ability, effort, adjustment to teacher, adjustment to classmates, handedness, and speech defects. A total of 1169 boys and girls in the first 4 grades served as subjects. On the basis of contingency coefficients and comparison of extreme groups, Farnsworth concludes that children rated high in music or art ability were found to be significantly better adjusted; there was a slight tendency for them to be more right-handed and to have fewer speech troubles. The ratings were found to hold up reasonably well over the period of a year.

It will be noted that all of the above results are primarily negative with respect to qualitative differentiation of the artist as a personality "type," although this point of view is held by popular as well as by certain serious writers. Seashore (1939), for example, in his discussion of the "musical temperament," concludes that the "artistic temperament" is typical of great musicians.

SUMMARY

In the present survey, an attempt has been made to provide a condensed picture of the field of artistic behavior in the abnormal, to view it in its general perspective, to indicate the various angles from which it may be approached, and to outline the major interrelationships between this field and other marginal fields or topics. This article represents the second in a series of literature surveys covering different aspects of the major field of artistic behavior in the abnormal. The first article of the series (Anastasi and Foley 1941a) deals with the historical and theoretical background; the third article (Anastasi

and Foley 1940b) is devoted to a more intensive survey of the literature on spontaneous productions of the insane; while the fourth article (Anastasi and Foley 1941b) similarly surveys the purely experimental investigations. Further articles will be concerned with the literature on special related phenomena, such as "trance" or mediumistic drawings and prison art. Although all of these articles are autonomous, the series should logically be considered together and in sequence for a comprehensive treatment of the field of artistic behavior in the abnormal.

Three distinct approaches to the phenomena of insane art have been differentiated. In the *artistic* approach, the abnormal production is viewed as an object of aesthetic regard, as illustrated by the numerous exhibits of products by the insane in galleries throughout the world. Conferences and lectures by artists, art critics, and others have frequently accompanied such exhibits. In such cases, the primary concern has been with the aesthetic value of the work, as well as with the particular techniques used by the patient in the creation of novel and "interesting" effects, some of which resemble those characteristic of certain schools of art. In fact, art products by abnormal patients have frequently served as a source of inspiration for various artists. Opposed to the majority of writers, who enthusiastically acclaim the artistic value of abnormal products, is a small group of conservative critics who deplore the tendency to elevate insane art.

A second approach to insane art is the *psychiatric,* which is in part concerned with the *diagnostic value* of the art product. Numerous claims have been made regarding the correlation between form of psychosis and characteristics of the drawing or other artistic product. There is considerable agreement among investigators in respect to such relationships in the case of certain syndromes, and to this extent such drawing characteristics can be employed as valid diagnostic indicators. The relationships are not so clear, however, in the case of other syndrome areas, where variability of drawing characteristics is large, so that considerable caution must be exercised in assigning diagnostic meaning to a given drawing peculiarity. Conclusions in this field are difficult to formulate with finality due to taxonomic differences and to lack of adequate empirical control.

Apart from the use of artistic productions of the insane as purely diagnostic indices, there remains an additional psychiatric use, *viz.,* their *therapeutic value.* This function of artistic production dates from ancient times, and includes almost every art form or medium. Positive results are frequently reported, most of them in the case of

drawing, painting, or music therapy. Again, precise quantification is not available due to taxonomic differences and to inadequate control data.

The third or *psychological* approach to insane art may be characterized by its predominant emphasis upon the perceptual, imaginative, or other intellectual as well as emotional functions leading to the production of such art. The abnormal products are studied primarily for the light which they may throw upon the basic mechanisms of behavior. Such psychological investigations are summarized in detail by the writers in the third and fourth articles of the present series, dealing with observational studies of spontaneous productions (Anastasi and Foley 1940b) and with experimental investigations (Anastasi and Foley 1941b), respectively. Many of these studies, using group survey or intensive case study techniques, have been concerned with the "psychology of art," *i. e.*, with an attempt to understand artistic production. Other psychological studies, employing a more nearly experimental methodology, have been motivated by an interest in the better understanding of the mechanism of perception, association, and ideational processes. In this connection, special mention may be made of recent Gestalt studies on drawing as an index of perceptual disorders. Another group of psychological studies has made use of drawing scales in the testing of intellectual development and "deterioration." The use of automatograph techniques and the observation of automatic drawing and "doodling" in normal and abnormal subjects, as well as in those in "trance" states and under the influence of insulin and other drugs, may also be included within the psychological approach.

A number of writers have pointed out the *resemblances* between the artistic productions of the abnormal and those of primitive, child, "populistic," and modern and fantastic art, as well as the art of particular cultural groups. Frequent comparisons have been made with the works of early masters, such as Hieronymus Bosch, as well as with the modern schools of expressionism, futurism, cubism, vorticism, surrealism, and dadaism. Among the resemblances which have been pointed out in the comparison of insane art with one or more of the above-mentioned fields of art are symbolism, mingling of inscriptions and drawings, use of hieroglyphics, obscure insinuations, play on words and sound or affective associations, neologisms, intellectual realism, ideoplastic representation, stylization, condensation, poverty of representation, abstract rather than realistic nature, subjective rather than objective portrayal, autism or lack of ulterior purpose, egocentrism,

individualism, humanized portrayal of objects, schism of content and formal tendencies, lack of auto-criticism, incongruous phantasy, uninhibited play, dissociation, distortion, absence of perspective, disproportion of hands and feet, "asyndesis" or poor integration, incoherence of forms, use of contradictory items, deformation and "dishumanization," exaggeration of particular details, serious qualities mixed with gross errors, bizarre and affected characteristics, ambivalence, repetition and perseveration, minuteness, imitation, lack of precision, lack of neatness, obscenity, sexual emphasis, avoidance of simple objects, arabesque tendencies, geometrical ornamentation and analysis, "mandala" design, automatisms, portrayal of morbid characteristics, employment of antithetical forms or colors or words, unusual use of color, attempts to obtain effects by use of spots, multiplication of elements to indicate motion, artificial division of the subject into different parts, and use of extraneous materials. A few investigators have called attention to the fact that although many such parallelisms can be found, there are likewise many outstanding differences, as, for example, the fact that the products in the various cases are the result of different etiological factors.

Much of the literature dealing with the problem of *genius and insanity* in art is theoretical and speculative, while the remainder deals with case studies purporting to show the abnormality of recognized professional artists of varying degrees of eminence and popular acclaim. The view that genius and insanity are closely related dates from the early Greek and Roman writers, and has been championed by a number of more recent psychiatrists, philosophers, anthropologists, and psychologists. The abnormalities reported range from peculiar mannerisms and eccentricities to more serious abnormal symptoms requiring institutionalization, and have been reported for all of the modes or forms of artistic expression. It is again apparent, however, that studies of the clinical histories of persons of genius showing abnormal symptoms represent selected cases, and that quantification and control data in the field of psychopathography are difficult to obtain. It has been pointed out, furthermore, that in a given case such a relationship between genius and insanity might be spurious and without causal significance. Some writers have also called attention to the large number of men of genius who have showed no abnormal symptoms.

The relatively few quantitative studies on the *relationship between personality traits and artistic ability* have yielded results which are primarily negative with respect to differentiation of the artist as a

distinct personality "type." It will be noted that these results, based on the general population, are at variance with the popular view and with the view linking artistic genius with insanity, discussed above. Evidence for the latter theories has been obtained on highly selected cases, which fact doubtless accounts in part for the otherwise apparent discrepancy.

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Annals of the New York Academy of Sciences
Volume XLII, Art. 2. Pages 113–272
October 15, 1941

THE FUNDAMENTAL PROPERTIES OF THE GALACTIC SYSTEM*

By

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H. R. Morgan, Jan Schilt, Frederick H. Seares,
Peter van de Kamp, and Emma T. R. Williams

CONTENTS

* This series of papers is the result of a conference on The Fundamental Properties of the Galactic System held at The New York Academy of Sciences, May 2 and 3, 1941.

THIS PUBLICATION IS DUE TO THE GENEROSITY OF MR. A. CRESSY MORRISON, WHO, THROUGH THE ESTABLISHMENT OF THE A. CRESSY MORRISON SERIES OF PRIZES IN ASTRONOMY, HAS STIMULATED MANY NOTEWORTHY INVESTIGATIONS ON THE SOURCES OF STELLAR ENERGY.

DEDICATED TO FRANK SCHLESINGER, WHOSE DEVELOPMENT OF METHODS OF ACCURATE PHOTOGRAPHIC ASTROMETRY IS THE BASIS OF MANY RECENT ADVANCES IN THE STUDY OF THE STRUCTURE OF THE GALACTIC SYSTEM.

THE REFERENCE SYSTEM OF STELLAR POSITIONS

By H. R. Morgan

From the Naval Observatory, Washington, D. C.

THE FUNDAMENTAL PLANES

We observe from the Earth and the motions which impress themselves upon us most are the daily rotation of the Earth on its axis, and the annual revolution of the Earth around the Sun. The planes of these motions, the equator and the ecliptic, are natural and convenient planes of reference having stable motions.

The position of the equator is determined directly by observation of the stars. It would be possible by observing continuously this position as it varies among the stars to set up by trigonometrical analysis an empirical law for its motion. But this is not done. The motion with its complicated nutation is due to the varying attraction of the Sun and Moon on the oblate rotating mass of the Earth, and gravitational theory therefore defines the motion. However, the mechanical ellipticity of the Earth, and the mass of the Moon are not given by observation with sufficient accuracy to determine the precession completely from this theory. The observed mass of the Moon from the lunar inequality[1] is uncertain by one part in four hundred, corresponding to an uncertainty of 10″. in the centennial precession, whereas the direct determination of the precession from observations of the stars is accurate to 1″. Hence the determining coefficients in the expansion, the precession and nutation constants, and the obliquity, are taken from observation.

The position and motion of the ecliptic depend upon observations of the Sun and planets among the stars, and upon the masses and motions of the planets.

We cannot consider here how observations are taken and reduced, nor the construction of star catalogs and planetary tables. Our subject suggests consideration of the positions and motions both of the stars and of the fundamental planes. And for convenience of reference, star catalogs are discussed first.

[1] **Astr Jour. 47 (1100). 1939.**

THE STAR CATALOGS

Within certain limits of approximation all individual catalogs of stars may, by intercomparison, be reduced to the system of a fundamental catalog. The fundamental system representing the most basic reduction of observations is the Third Fundamental Catalog of the Berliner Jahrbuch, referred to as the "FK3." This system is the result of an exhaustive investigation by A. Kopff and his associates for the last twenty years, the outlines of which are given in numerous papers in the Astronomische Nachrichten. It is a revision and extension of the Auwers system, the NFK. It has been adopted by the National Almanacs upon recommendation by the International Astronomical Union. The Astronomer Royal[2] has expressed the opinion that the FK3 system is undoubtedly the best available and the nearest approach to a true system at present. I believe this is the general opinion.

In constructing the catalog the most approved and exacting methods were followed for eliminating periodic errors varying with right ascension in different zones of declination, and errors varying with declination, and in determining the positions of the poles and the equinox. To establish the position of the equator among the stars Newcomb used observations of the Sun, Moon, and planets, and his declinations have held good for 70 years. This basic method of establishing a fundamental point in declination 90° from the poles has been followed in constructing the FK3.

Investigations at the Naval Observatory[3,4] of observations of the Sun, Moon and planets since 1900 uphold definitely both the equator point and the equinox adopted in the FK3. The declinations in recent Washington catalogs from fundamental observations agree with the FK3 declinations within $0''.1$ over an arc of 120°, and recent Cape observations check the smallness of periodic errors in right ascension. The systematic errors are doubtlessly reasonably small. The probable errors of the centennial motions are estimated as about $\pm 0''.2$. The authors cautioned that the proper motions are far from being definitive as they are based upon observations since 1850 and the catalogs between 1850 and 1900 are not free from systematic errors.

Evidence as to the accuracy of the positions and motions as to periodic errors is afforded by comparing the corrections to the Preliminary General Catalog, referred to as "PGC," as derived in con-

[2] Month. Not. Royal Astr. Soc. 99: 424. 1939.
[3] Astr. Jour 42 (987). 1933.
[4] Astr. Jour. 41 (969). 1932.

structing the Albany General Catalog, referred to as "GC," with the corrections to the same catalog given by the FK3.[5] The two independent investigations give quite similar corrections to PGC for periodic errors in right ascension in equatorial regions as follows:

Corrections to the PGC and GC (1950)

From (GC)	$\Delta\alpha = -^{s}.009 \sin\alpha + ^{s}.012 \cos\alpha - ^{s}.002 \sin 2\alpha + ^{s}.006 \cos 2\alpha$
From (FK3)	$\Delta\alpha = -.011 \sin\alpha + .011 \cos\alpha + .002 \sin 2\alpha + .008 \cos 2\alpha$
From (GC)	$100\ \Delta\mu = -.005 \sin\alpha + .009 \cos\alpha - .003 \sin 2\alpha + .006 \cos 2\alpha$
From (FK3)	$100\ \Delta\mu = -.009 \sin\alpha + .004 \cos\alpha + .007 \sin 2\alpha + .010 \cos 2\alpha$

These errors do not represent uncertainties in modern observations. All series give similar corrections to the catalogs. Standard observations today admit no such errors. They were possible 100 years ago.

The Albany General Catalog of 33,342 stars, by Benjamin Boss and his associates, is the next important recent fundamental catalog. This is a revision and extension of the Preliminary General Catalog of 6188 stars, by Lewis Boss, and as many important studies in stellar motions have been made using one of these catalogs, or motions of fainter stars reduced to them, they may be considered together. The equator points for the declinations were not determined from observations of the Sun and planets and, as a consequence, the systematic errors of the PGC equatorial declinations amount now to over $0''.5$, with corresponding errors in proper motion. These errors were only partly corrected in passing to the GC, the declinations of which require now a positive correction of $0''.2$, on the average, with a variation of $0''.5$ in the southern sky, while the centennial motions require corrections of twice these amounts.

As stated above, in the Introduction to the GC a discussion of standard observational catalogs shows clearly the large and well known periodic errors varying with right ascensions in the PGC system. These errors amount to $\pm 0''.3$ in the right ascensions and $\pm 0''.3$ in the centennial motions. They have been well established by other discussions. They change phase with time so that they enter with full force into the proper motions of the catalog.

No corrections for these large errors were applied to the PGC in forming the GC system, and this virtually established a system of star places which definitely fails to represent the observations upon which it is supposed to be based. This was a most regrettable procedure. It will have a deleterious effect for years to come. This is

[5] Astr. Jour. 46 (1063). 1937.

already shown in a recent tabulation of some corrections to the GC by Smart.[6] As just shown, the corrections to the GC motions (FK3-GC), have periodic terms similar to terms in precession and galactic rotation. What are designated in the Wilson-Raymond[7] solution as corrections for precession and rotation are partly the systematic errors shown in the Introduction to be in the catalog itself. The corrections tabulated do not free the catalog from its important errors, and their use would tend to introduce an unknown precession into star places. The precession is a fundamental constant and should be changed only with a general and consistent change in the whole system of fundamental constants, and with the approval of the International Astronomical Union.

The systematic errors of the GC proper motions range up to 1″.0, especially in the southern hemisphere, and they are of the same order as the quantities sought in solution for precession, solar motion, and rotation. When expressed in periodic form they give approximately the following:

$$100\ \Delta\mu = -0''\ 11 \sin\alpha \sec\delta + 0''\ 10 \cos\alpha \sec\delta$$
$$100\ \Delta\mu' = 0\ \ 00 \cos\alpha \qquad - 0\ \ 11 \sin\alpha$$

The first terms in each case enter as unreal precession and the second terms as unreal rotation. Small weight can be given to corrections to fundamental constants from such solutions until known errors are eliminated. These errors are so involved with the positions and motions of the catalog that it may be impossible to correct for them now by internal computations. The conclusion is therefore that the positions and motions of the GC can be used for basic results only by applying to them the systematic corrections (FK3-GC) given in A. N. Band 269; and a similar statement applies to the PGC with the corrections (FK3-PGC) given in A. N. Band 255. And this is important. The large number of stars in the GC and the comprehensive scope and fundamentality of the catalog render it an indispensable medium of comparison for all fainter star work. Systematic corrections are now available so that all old catalogs may be reduced to this standard; and more recent catalogs give comparisons in their introductions. With the new positions of all stars to the 9th magnitude, now being reduced, it will be possible to re-reduce any astrographic position to this standard.

It is almost a universal practice for computers of individual

[6] Month. Not. Royal Astr. Soc. 101: 37. 1941.
[7] Astr. Jour. 47 (1084). 1938.

meridian and photographic catalogs to take positions of reference stars from the fundamental catalogs unchanged. The errors of the PGC have long been known and for rigid work corrections have been applied, but in much differential work they have not been.

A word further may be said as to motion of faint stars where the end catalogs have been reduced through reference stars to a standard. The motions depend upon the errors in the end catalogs, the errors of comparison, and the errors in the standard motions, and with small divisors for short intervals the resulting systematic errors may be larger than the deduced proper motions. It is impossible to get very reliable motions in 10 or 20 years. The errors of the end positions are too large. It seems necessary to bring out that solutions from faint star groups or catalogs have given similar results for precession because they are all reduced to the same standard. Kopff considers that the errors in the fundamental systems have great weight in the comparison with faint stars as they may be comparable with the total motion of such stars.

The excellent work on star motions that is being carried on is all important and the results are valuable in the development of the subject. My caution is to keep our observations clearly and uniformly reduced in such a way that those who follow may use them more intelligently than we can use some of those in the past. De Sitter[8] in speaking of Newcomb's work says, "It would certainly be premature to make a new determination either of the constant of precession, or of the elements of the planets—before the present uncertainty regarding the systematic errors in the declinations and the proper motions in declination of the stars has been cleared up." The systematic errors in declinations observed and reduced fundamentally are much smaller today than those considered by de Sitter. The mean epoch for position in the fundamental catalog is around 1900, and Schlesinger has shown that the errors of the GC positions, brought up with their proper motions to the present, run over a third of a second of arc. Our present observations have smaller errors than this.

THE OBSERVATIONS

The points in the sky best determined by observation are the poles of the equator, or the axis of the Earth's rotation. These points are determined very accurately by observing the stars both above and below the pole for the polar point of the circle, and for a zero point

[8] Bull. Astr. Inst. Netherlands No. 129. 1927.

of the instrumental meridian. All absolute declinations include solutions for the polar point, latitude, and refraction, and all instruments agree in the coordinates of the stars at the pole, the systematic errors being smaller there than elsewhere in the sky. In going away from these points the instruments often diverge, and differ as much as 1″.0 or more at the equator. Only a few government observatories can carry on continuous Sun, Moon, and planet work necessary for determination of a second fundamental point of reference at the equator. The equator is not observed but the ecliptic is—through the motions of the Sun and planets. The plane of the ecliptic is then the second fundamental position given by observation. The average declination of the ecliptic is the equator, and the obliquity is measured by the circles, influenced, of course, by refraction, flexure, division errors, day terms, and so on. One of the great difficulties here has been the day terms. It is necessary to observe the bright stars as near the Sun as possible in order to determine the difference between the day and night observations, which, with the Washington instruments for instance, range up to 1″.0 in declination and ^{s}.04 in right ascension.

Investigators agree that the pole points among the stars are well determined, but there is more uncertainty in the position of the equator and the ecliptic. In my own discussion, night observations of the outer planets and the Moon were included. These are free from the uncertainties of day terms. There is more uncertainty in observation of the Moon, but its rapid motion in both coordinates is an advantage. Newcomb considered that occultation results were quite comparable with meridian results for determining the motion of the equinox. These have been discussed by Jones. The observations of Mercury and Venus have an uncertainty in personal equation due to the form of the visible disc which enters into all methods of observing, and may not be materially reduced by travelling threads; but such errors largely mean out in a synodic period. Two recent and rather exhaustive discussions of all available material by Heineman[9] and Morgan,[8] agree with the position of the equator among the stars established by Newcomb.

The correction to the obliquity itself is very small, but the observed centennial motion is larger than that computed by Newcomb, by 0″.2, and corresponds to a larger mass of Venus. The periodic perturbations of the Earth by Venus recently deduced from the Sun observations, and other determinations, also give a larger mass for Venus.

[9] Astr. Nachr. 241 (5769). 1930.

THE EQUINOX

The equinox to which right ascensions are reduced is that determined by Newcomb 70 years ago by comparing observations of the Sun 1750–1870, with observations of 32 bright stars; and slightly modified ten years later to be defined by the positions and centennial variations of 128 bright stars within 40° of the equator. The new system FK3, gives the same mean centennial variation for these 128 stars as that used by Newcomb.

Numerous investigations for correction to this equinox have been made using different series of meridian observations of the Sun, Moon and planets, and occultations of stars by the Moon. All results show that the equinox itself must be changed a large part of a second of arc to conform to changes in methods of observing. The results from standard observations for position of the equinox with regard to the clock stars at a given time vary $0''.3$, with a mean accurate to $0''.1$.

In the three most recent and more complete investigations by Jones,[2] Kahrstedt[10] and Morgan,[4] the evidence is rather conclusive that Newcomb's motion of the equinox satisfies the best reductions of observations we can make within $0''.1$ or $0''.2$. Results from recent observations at Cape and Washington, and a discussion of Hornsby's observations (1785) have been added to my last solution with practically no change in the results. In that solution $^{s}.025$ was applied for change from key observations to travelling thread registration, and some have questioned this correction. It is, however, well established; the change at Greenwich was $^{s}.03$, at Washington $^{s}.02$, at Cape $^{s}.02$, and at Pulkowa $^{s}.04$. The relative personal equations on the Sun and on the stars using the key method, may have changed some from 1850 to 1910, and there may be a small uncertainty in the equinox motion due to personal equations which only time and modern methods can eliminate. The magnitude equation has been more or less persistent and similar for all observers. The change from eye and ear to key observations was small at Greenwich and large at Cape and Pulkowa, and is, of course, more uncertain. Newcomb concluded that for the standard catalogs the personal equation was nearly the same for eye and ear and for key and chronograph. Omitting the first 100 years of eye and ear work changes the solution for equinox motion very little, however.

Thackery[11] has shown that the annual terms in declination due to variation of latitude may at times change the derived longitude of

[10] Astr. Nachr. 244 (5835). 1931.
[11] Month. Not. Royal Astr. Soc. 85: 1000. 1925.

the Sun, and hence the equinox correction by as much as $^{s}.02$. As the latitude variation was not regularly observed last century, there is an uncertainty because of it, but this must be very small on the average over long periods. Other possible annual terms in the Sun's declination may produce errors in the obliquity and in the equinox.

As stated before, the intensive study of day terms at present is doing away with such errors to a much larger extent than was possible in the old work. The almost perfect modern clocks under constant temperature and pressure give dependable time at all hours of the day and night, and these together with the synchronous motor drives for micrometer threads as developed by Watts at the Naval Observatory, other instrumental improvements, and stable meridian marks for azimuth work assure far more accurate results now than were ever before possible. Observations became more accurate in the middle of the last century with the introduction of several new large transit circles and vertical circles, and with the key substituting for the eye and ear work; and in establishing the new star systems only the observations since 1850 have been used. The older observations are used only in general analyses and for individual proper motion. With the planetary work, however, the condition is different. The first 100 years are necessary for the secular terms in the motion of the planets, and for the Sun and Moon the secular accelerations of the longitudes are even determined from ancient eclipses.

We must conclude that the position of the equinox with regard to the clock stars is very accurately determined at the present, and that its motion is so well established it cannot be changed by any such amount as $1''.0$ per century suggested by some recent studies of stellar motions.[4,10]

By definition this motion is not precession. It is the relative motion of the equinox point and some more or less permanent list of 200 to 300 equatorial bright stars used as clock stars—they must include the brightest stars for observation in the day time with the Sun. And the motion of the bright stars relative to the mass of stars, or to some fixed direction in space, must be added to the above motion in order to get precession. I quote from Newcomb,[12] "We therefore have three separate steps in determining completely a correction to the adopted annual precession.

[12] **Newcomb, S. "The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy." p. 125. Government Printing Office, Washington, 1895.**

(1) "The correction to the Sun's absolute mean right ascension, or longitude. (From the observed declination.)

(2) "The correction to the general mean right ascension of the clock stars relative to the Sun. (From the observed right ascension.)

(3) "The determination of the clock stars relative to the great mass of stars. (From the catalogs.)"

and continuing he says, "The motion of the pole of the equator upon which the luni-solar precession depends may be determined by observed declination quite independently of the right ascension."

The positions and centennial motions of the clock stars relative to the mass of stars may have appreciable errors, possibly as large as $0''.5$. The average proper motion of our present clock stars is about $-1''.0$ a century, and the equinox motion by definition should therefore differ from precession by $1''.0$, and it does.

The indeterminateness of certain solutions may be noted. In the first place most of them have used proper motions based upon the PGC or GC systems, the systematic errors of which are large and may be expressed as periodic terms similar to those in precession and rotation as already shown. For motion in galactic latitude, the proper motions in right ascension and declination, both of which are affected by the above errors, and with rotation, are both used, by transformation, to get motion in galactic coordinates such that the computed motion in galactic latitude has in it systematic errors and rotation. Moreover, the equation in latitude[13]

$$\Delta\mu_b = \Delta p \sin \epsilon_1 \cos (g - g_1) - (\Delta e + \Delta\lambda) \sin \epsilon_2 \cos (g - g_2)$$

lacks fundamentality for two other reasons. The quantity Δe here refers to the motion of the equinox with reference to a fixed direction and it is therefore pure precession, as is Δp. Again, the coefficients are nearly equal and opposite in sign, the angles differing by only 27°, rendering the equation indeterminate in character. In the solutions the two unknowns come out nearly equal—as they should, both being corrections to the same precession—and with a value of $1''.0$. But the equation would be about as well satisfied with unknowns twice, or one-half, this value. Corrections to fundamental constants derived from such solutions have less weight.

That the constant term in the proper motions in right ascension gives a correction to the motion of the equinox of the clock stars is

[13] Bull. Astr. Inst. Netherlands No. 132. 1927.

also misleading. The clock stars are Bradley stars. It will be shown later that for the Bradley stars corrections for unequal distribution in the two star streams change Newcomb's constant term $0''.56$, and Struve's $0''.77$, reconciling the constant terms with the periodic terms. The constant term in the right ascension motion contains also possible personal equation and rotation effects for the fainter stars relative to the brighter stars.

And here the opinion of de Sitter[14] is again of value. He considers that in these solutions "the precession and the motion of the equinox are very badly separated, and moreover the proper motions in galactic latitude being derived from those in right ascension and declination are affected with the systematic errors of the latter," and continuing he says, "it appears safer to keep separate the proper motions in right ascension and declination which have their own largely unknown systematic errors. They must then before serving for a determination of the precession be corrected for galactic rotation, the constants of the latter being derived from radial velocities and the periodic terms in proper motion."

THE PRECESSION

In Newcomb's solution for precession, which gives a smaller value of the precession from the proper motions in right ascension than from those in declination, he says[15] "We cannot attribute the difference to the variation of personal equation with magnitude because we have reason to suppose that the error is one which affects the modern (key observations 1850–1890), more than the older observations (eye and ear), and which would, therefore, make the precessional motion derived from right ascensions come out too large." This he finds to be the case for the faint stars of Lalande. This condition is reversed now, the key observations with large equations are the earlier, and the travelling threads with small equations the later, and the right ascension motions come out smaller, as predicted.

Kopff[16] suggests that the present systematic corrections to standard catalogs are not free from magnitude effects even for the 30,000 bright stars, and that it is necessary to establish fundamental motions of some 3,000 stars from the 6th to the 9th magnitudes free from magnitude effects so as to go back properly to the faint stars in the older catalogs for motions. This again expresses the idea that in

[14] Bull. Astr. Inst. Netherlands No. 307. 1938.
[15] Astr. Pap. Am. Eph. 8: Pt. 1. 54. 1898.
[16] Month. Not. Royal Astr. Soc. 96: 729. 1936.

the present motions the bright stars have an unknown motion on the fainter background. And this can be eliminated only by determining motions for the faint stars free from personal equation or other errors. This has been done over too short a period as yet for definitive results.

There are, too, errors in right ascensions at higher declinations arising from errors in pivots, flexures, determination of the pole point and of the azimuth and collimation of the instruments, and in personal equation varying with declination. In this way the stars at higher declinations may not be referred to the clock stars in the same way at different epochs, with the result of an unreal relative motion. Also while the declinations at the poles are quite accurately determined at all epochs, those at the equator may have quite different errors at one epoch than at another, due to errors in determining the equator points. Instrumental flexures, personal equation in bisection, difference between day and night seeing and refraction, and other errors enter into the reductions in varying amounts at different times. In this way systematic errors in proper motion in declination are introduced. The average proper motion in declination of the GC requires a positive correction of $0''.2$.

For the determination of the equinox it is necessary and sufficient to have reference to a small list of equatorial bright stars, and these may have motions. But with the precession it is different. Here the influence of the motions of the stars themselves add greatly to the problem. Eddington[17] says "that on the basis of the two star drifts the present methods of calculating the precession are only approximately (and one may almost say accidentally) correct." Jones[2] calls attention to the fact that "the existence of two star streams, or a preferential direction of motion, or the rotation of the galaxy is not in accordance with the fundamental assumptions on which Newcomb's value of the precession was derived. The value obtained for the precession will depend upon the particular assumptions made." The derived precession constant changes as we change from group to group of stars corresponding to changes in the sum total of the proper motions, and to unknown group motions. In passing from the 3,000 Bradley stars observed from 1750 to 1890 to the 30,000 GC stars based on observations from 1850 to 1925, the value of precession appreciably increased. On the other hand, all recent solutions based on the PGC, or GC motions, or on motions reduced to one of these standards, give quite similar corrections to the precession, as they virtually reproduce the standard.

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[17] Month. Not. Royal Astr. Soc. **67**: 34. 1906.

L. Struve[18] and Newcomb[15] made solutions using old observations of some 3,000 Bradley stars, Struve found a rotation $-0''.4$, while Newcomb omitted such a term. Otherwise, the two results agree fairly well, and in each the correction to precession from the proper motions in declination is considerably larger than that from the right ascensions. Boss in discussing the 6,000 PGC stars found a similar discordance, as have Wilson and Raymond with the GC stars. This has been attributed partly to a motion of the equinox. In such solutions the periodic terms, especially those in declination are taken as the determining result, and the residual in the constant term has been attributed partly to other causes. Hough and Halm[19] have shown, however, that the effect of unequal distribution of the two Kapteyn streams gives a correction to the constant term in right ascension which reconciles it with the precession determined from the periodic terms in declination and right ascension. This correction has been accepted by de Sitter and by Eddington. In Newcomb's solution the constant term was changed $0''.56$, and an additional term $0''.56 \cos 2\alpha$ given by the same theory, satisfies an unexplained term found in the observations. It has been shown that streaming extends to fainter stars, and an effect from this may be present in all solutions.

Again, the rejection of large proper motions strongly affects such solutions. In these solutions the solar motion was discussed assuming that the stars in the 108 areas were at equal distances. Information as to parallax accumulates slowly, but possibly a better assumption as to distance could be made now. No term for rotation in the ecliptic has been included; some evidence of such a motion has been found.

No extensive determination of the precession on the FK3 basis has been made, but an approximate value has been determined in the Raymond-Wilson paper[7] by applying the systematic difference in proper motions, FK3-GC, in each of the GC area equations. The precession correction comes out about $+1''.0$. Schilt has also used the FK3, and with similar results.

There is a fundamental difficulty in the unknown motions of the standard stars, such as an unknown rotation, that cannot be overcome by going to the fainter stars. For these latter objects are by necessity of observation referred to the bright stars around them. Now while the faint objects may in themselves have little or no cosmic motion, yet by the nature of the reduction we endow them with the

[18] Astr. Nachr. 159 (3816): 1902.
[19] Month. Not. Royal Astr. Soc. 70: 568. 1910.

unknown motions of the standards which we wish to avoid. And therefore in the solutions for precession the faint and bright stars give quite similar results. For instance,[20] the 18,000 McCormick stars were afflicted with the motions of 574 Boss stars, and then gave Δp, $+1''.01$; while the Boss stars by themselves give Δp, $+1''.00$.

It may be possible in the future, by equating to zero the mean of the motions of the 200,000 faint stars now being determined, and by using the relative motions of these stars and the bright stars, to determine new motions of the standard system, and thence the precession, allowing, of course, for rotation and solar motion in the solution.

Suggestions have been made that, as a means of avoiding the influence of unknown star motions, the distant galaxies be used as a reference system having inappreciable motions. A program at the Lick Observatory has this in mind. The reduction problem will be to get the plate star positions and motions rigidly on the system of standard stars to which the precession now in use refers. The galaxies are poorly distributed, and few are visible within 20° of the galaxy. But eventually it may be possible to work inward from the galaxies as a fixed system, through relative motions to the faint and then to the bright stars of the standard system. The new standards would then include all unknown rotations or streaming, and the resulting precession should approximate the dynamical value.

As to the planetary precession, the conclusion now is the same as that held by Newcomb, namely, that it cannot be changed over $0''.1$ or $0''.2$ by any admissible changes in the masses. It has been computed two or three times independently with exact agreement. The reciprocals of the masses of Mercury and Venus used in computing this motion are 6,000,000 and 408,000, and the best known values now are not far from 7,000,000 and 406,000, corresponding to changes of $-0''.106$ and $+0''.092$ in the motion.

The evidence is, therefore, that Newcomb's centennial precession requires a correction of nearly $1''.0$ to satisfy the mass of proper motions referred to the present fundamental system. This evidence is deduced mainly from the periodic terms over the sky, and is uncertain by, say, a fourth of its amount. It is necessary to examine as to whether a change of this amount is consistent with other constants and theoretical relations in the present system.

All observations as made are apparent places, they must be reduced using precession, nutation, aberration, obliquity, and so on, and these and other constants are inseparable from the final star places. The

[20] Bull. Astr. Inst. Netherlands No. 298. 1937.

value of the precession now in use is 0″.8 larger than that used in the tables of the planets. The constants enter into the planetary tables in many ways. The mean longitudes, the longitudes of perihelion and node, are all carried forward with precession. The ephemerides of the planets have these constants in them. The different values of the constants used in the old ephemerides and in reducing the old observations produced uncertainties in the comparisons of observations so that it is often necessary to carry back the present tables and recompute ephemerides of comparison in order to get the old observations uniform with the new.

The precession in most star catalogs for the last 40 years has become such an integral part of the proper motions, investigations and system of fundamental constants that it would be very confusing, and inadvisable, to make a change until a revision of the whole planetary and fundamental system is made.

De Sitter[14] thinks "a revision of our official system of fundamental constants has become desirable, such a revision, however, should not be piecemeal but embrace the whole system. It is of much greater importance that the value of a fundamental constant should be exactly defined than that it should be the best available at the moment. The secular retardation of the rotation of the Earth should be taken into account in the construction of the system of fundamental constants, also the relativity theory in the precession of the equinox and motion of the planets." De Sitter and Brouwer have published a classical paper[21] on the theoretical relations among the various constants and reduction elements in the planetary and coordinate system, together with numerical values of the constants, including the secular accelerations in the longitudes of the Sun and Moon, the fluctuation in the Earth's rotation, and the relativity effects.

NEW WORK

We may now look forward to proper motion solutions based on the new system, and using a new and large amount of material now becoming available. The motions of 14,000 reference stars spaced over the northern hemisphere just observed for the revision of the A. G. catalogs and rigidly reduced to the FK3 basis will soon be available for discussion, and this should be valuable also on account of its homogeneity. Recent observations at Cape of 15,000 stars spaced over the southern hemisphere are now ready for publication. Also the photographic observations of all stars in the sky to the 9th magni-

[21] Bull. Astr. Inst. Netherlands No 307. 1938.

tude and fainter will before long furnish motion of upwards of 200,000 stars. Schlesinger[22] suggested 20 years ago that fully 100,000 highly accurate proper motions are required to settle problems that are at present urgent. In the future it may be possible to repeat the Astrographic program, and by means of definitive motions of the A. G. reference stars compare the new and old for mass motions of faint stars.

The growth of stellar dynamics has greatly enlarged the demand on standard observations which now become more concerned with precision measures relating to objects in all parts of space. The general stellar motions become in turn of vital importance in improving the coordinates of reference and the motions in the solar system. In the solar system the determination of the distances of the objects forms a most important part of the problem; the same is true in the general problem of stars; but for determining the coordinate planes and directions, the distances of the stars are considered only in connection with solar motion. The parallaxes of the stars have a greater uncertainty in them than the proper motions.

As planetary motions may be determined only by reference to positions of the stars, and the star places are in turn defined with reference to coordinates determined from the planets, continuous observations are required both of the planets and of the stars.

The observations since Newcomb's time are sufficient to double the weight of his planetary results, and proceeding with the new fundamental star places and the modern observations of the Sun and planets, we now look forward to a general improvement in the motions and constants of the solar system. Already for some of the planets the reductions are underway. The observations of the Sun, Mercury, and Neptune have been reduced and discussed—those of the Sun in many ways. The results show a real correction to the Earth's eccentricity, and this, with the fluctuation in its longitude, gives a correction to the Sun's longitude at present as follows:

$$DL = +1''.00 + 0''.30 \sin (\alpha - 135°)$$

For work on definitive orbits the solar coordinates should be corrected by this amount at present. Corrections to the mean longitudes, the motion of the obliquity, the mass of Venus, and the mass of the Moon have been found. Rediscussions of the observations of Venus and Mars are necessary for information as to the masses of Mercury and Venus, as well as for the motion of the Earth. The theories of

[22] Publ. Am. Astr. Soc. 4: 344. 1922.

Neptune and Uranus are being revised. A value of the mass of the Moon and of the nutation constant will result from the Eros parallax work.

Important independent information as to the positions of the coordinate planes among the stars may be expected from the accurate study of a group of minor planets now being carried out by Brouwer, using photographic observations.

SUMMARY

1. The basic catalog for all fundamental work is the FK3, which represents the nearest approach to a true system at present.

2. The catalog best adapted for general catalog comparisons is the GC, which contains a large number of positions and motions on a homogeneous system. This catalog has well established errors, corrections for which are published, and should be used.

3. Modern observations require a correction to Newcomb's equinox of $0^s.04$, or $0^s.05$, and such corrections have been incorporated in present catalogs. Newcomb's motion of the equinox referred to the clock stars is the motion that best satisfies the observations of the Sun, Moon, and planets.

4. Newcomb's centennial precession requires a positive correction of approximately $1''.0$ to satisfy general solutions from proper motions corrected for systematic errors, solar motion, rotation and streaming.

5. The positions of the equator and ecliptic are probably known within $0''.2$. The equator and equinox are defined by the FK3 system.

6. Modern observations are furnishing considerably more accurate determinations of certain elements of the reference system than were possible a few decades ago.

7. The planetary observations are being investigated for corrections to elements, constants and masses. Fluctuation and relativity effects are taken into account. Theory is being revised for some of the planets.

8. The theoretical relations between the constants and elements in the fundamental system have been given by de Sitter and Brouwer.

9. It is not advisable to make changes in the constants until the whole fundamental system can be revised.

THE REFERENCE SYSTEM WITH A VIEW TO PLANETARY DYNAMICS

By Dirk Brouwer

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The current interest in the use of minor planets for the improvement of the systems of fundamental catalogs was initiated by a statement made by Sir Frank Dyson at the Leiden Meeting of the International Astronomical Union.[1] Dyson recommended observations of Vesta for the purpose of checking the equator point of transit instruments.

Dneprowsky[2] and Subbotin[3] extended Dyson's suggestion, and recommended that observations of Vesta, Ceres, Pallas, and possibly Juno be included in fundamental meridian circle programs. While Dneprowsky considered the use of the minor planets for the improvement of the fundamental declinations only, Subbotin emphasized their importance for the determination of the equinox correction.

Numerov[4] chose ten asteroids with small inclinations and small eccentricities, and recommended their observation with both meridian circles and photographic telescopes. Like Dyson and Dneprowsky he was principally interested in the improvement of the declination system.

A study of the problem, which was stimulated by Numerov's paper, led me to propose a plan[5] of observing selected minor planets for the purpose of obtaining systematic corrections to both right ascensions and declinations within the zone of the sky between declinations +30° and −30°. The minor planets for this program were chosen principally with a view to having this half of the sky covered as uniformly as possible by the observations during a ten-year program. The original list contained fourteen minor planets. To these have been added two additional ones, (27) Euterpe at the suggestion of Dr. Keivin Burns, and (433) Eros at the suggestion of Dr. G. Stracke.

The present program consists of observations of the following planets:

[1] Trans. Intern. Astr. Union 3: 227.
[2] Bull. Obs. Centr. Poulkovo 13 (1): 1932.
[3] Poulkovo Obs. Circ. No. 3. 1932.
[4] Bull. Inst. Astr. Leningrad No. 32. 1933.
[5] Astr. Jour. No. 1022. 1935.

No.		i	φ	a
1	Ceres	10°.6	4°.5	2.77
2	Pallas	34 .8	13 .6	2.77
3	Juno	13 .0	14 .9	2.67
4	Vesta	7 .1	5 .1	2.36
6	Hebe	14 .8	11 .7	2.43
7	Iris	5 .5	13 .3	2 39
12	Victoria	8 .4	12 .7	2 33
25	Phocaea	21 .6	14 .8	2.40
27	Euterpe	1 .6	9 .9	2.35
57	Mnemosyne	15 .2	5 .8	3.16
185	Eunike	23 .3	7 .4	2.74
216	Kleopatra	13 .1	14 .5	2.79
287	Nephthys	10 .0	1 .3	2.35
409	Aspasia	11 .3	4 .1	2.58
433	Eros	10 .8	12 .9	1.46
532	Herculina	16 .3	10 .3	2.77

Photographic observations were commenced in April, 1935, at the Yale Station in Johannesburg. In September, 1935, the Allegheny Observatory began its cooperation in this work. From that time on, Dr. Keivin Burns has given the program his most enthusiastic support. Shortly afterwards Dr. G. van Herk of the Leiden Observatory began a series of observations, first with the meridian circle,[6] later with the 13-inch photographic refractor.[7]

Owing to this cooperation the program has grown from a tentative scheme to an undertaking of considerable size. After six years of work it is not yet possible to make any claims for the degree of success that we may expect. So far as our evidence goes, there is every reason to believe that the results will justify our efforts.

Yale Observatory has undertaken the measurement and reduction of all the plates, with the exception of those secured at Leiden. This work, which involves the measurement and reduction of some 600 plates a year, added to that of providing search ephemerides, securing accurate orbits, and making the discussion of the observations was a heavy burden to assume. We are, therefore, greatly indebted to the Carnegie Institution of Washington whose substantial financial support is enabling us to proceed with the program without dangerously retarding the progress of other research projects of the Observatory.

In the present paper an attempt is made to discuss the various problems that are presented by this program. In earlier sections

[6] BAN 8: 35, 202. 1937.
[7] BAN 9: 37, 163. 1940.

questions of more fundamental and theoretical nature are considered, then follows a presentation of the more practical details of the work.

THEORETICAL FOUNDATION OF THE METHOD

The theoretical possibility of a dynamical foundation of the reference system has long been recognized. The first extensive practical application of this method was made by Newcomb in his well-known discussion of the observations of the Sun, and the planets, Mercury, Venus, and Mars.[8] This approach to the problem of defining a reference system has, therefore, been justly called Newcomb's method. A first outline of the procedure followed in his Astronomical Constants was written in 1882,[9] but as early as 1877 Newcomb must have had a comprehensive plan of the work that was to occupy him for thirty years, and that constituted his greatest contribution to astronomy. Newcomb's discussion of the observations of the Sun, Moon, and principal planets has been continued by astronomers connected with the observatories at Greenwich, the Cape of Good Hope, and Washington, but no complete discussion of the numerous accurate observations accumulated since Newcomb's time has yet been made.

The principle of the method is most clearly stated in the case of the Sun.[10] For simplicity, assume that meridian circle observations permit the determination of absolute declinations in a zone near the equator, say 30° on either side, with errors that do not depend on the right ascension. In this case the observed declinations in a series of observations require either a constant correction or one that may depend upon the declination.

Now if the Sun be supposed to move in a fixed great circle in the sky, and if the obliquity of the ecliptic be ϵ, the observed declinations give rise to an equation obtained by differentiation of the relation

$$\sin \delta = \sin \epsilon \sin \lambda,$$

namely,

$$\Delta\delta_0 + \cos \alpha \sin \epsilon \, d\lambda + \sin \alpha \, d\epsilon = (O - C)_\delta.$$

The added term in the left-hand member determines the correction to the equator point. Its interpretation is that the observed declinations require the correction $-\Delta\delta_0$; thus

$$\delta_{\text{true}} = \delta_{\text{obs}} - \Delta\delta_0.$$

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[8] The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy, 1895. (= Astronomical Constants.)

[9] Astr. Pap. Am. Eph. 1: xii–xiv.

[10] Astr. Const. 15–17.

The correction $d\lambda$ is the correction to the Sun's absolute true longitude, *i. e.*, the Sun's longitude counted from the intersection of the ecliptic with the equator.

If the Earth's motion around the Sun may be represented by an elliptic orbit, there will be four constants that determine the motion of the Sun in the ecliptic, namely,

the mean motion, n',
the mean longitude at epoch, l_0',
the eccentricity, e',
the longitude of the perihelion, π'.

Since the correction to the mean motion is small, one may ignore this unknown if the period covered by the observations is short enough. For the Sun Newcomb used groups of from four to eight years. The declination observations thus require the introduction of five unknowns,

$$\Delta\delta_0,\ d\epsilon,\ dl',\ de',\ e'd\pi'.$$

The practice of observers with the meridian circle is to base their right ascensions on the assumed right ascensions of a set of clock stars. From the formula

$$\tan\alpha = \cos\epsilon \tan\lambda$$

in which α, λ are the absolute right ascension and absolute true longitude respectively, *i. e.*, both counted from the intersection of the ecliptic with the equator, one obtains:

$$\Delta\alpha_0 + \cos\epsilon \sec^2\delta\lambda - \tfrac{1}{2}\sin\epsilon \sin 2\lambda \sec^2\delta\epsilon = (O - C)_\alpha.$$

The added term in the left-hand member represents the correction to the right ascension system of the clock stars, so that

$$\alpha_{\text{true}} = \alpha_{\text{obs}} - \Delta\alpha_0.$$

The usual definition of equinox correction is $E = -\Delta\alpha_0$, the equinox correction being the correction that must be applied to the right ascension system of the clock stars.[11]

If again the three unknowns dl', de', $e'd\pi'$ are introduced to replace $d\lambda$, it appears that the equations from the observations of the Sun's right ascension will require the introduction of the five unknowns

$$\Delta\alpha_0,\ d\epsilon,\ dl',\ de',\ e'd\pi'.$$

[11] Newcomb, "Compendium of Spherical Astronomy," p. 329.

It is therefore possible to make one solution which includes both the right ascension and the declination observations of a given series, and obtain the six corrections,

$$\Delta\alpha_0,\ \Delta\delta_0,\ d\epsilon,\ dl',\ de',\ e'd\pi'. \tag{A}$$

It is immaterial that this procedure is never followed in detail. The principal reason is that some advantage is gained by dealing separately with the right ascensions and the declinations. Moreover, since the corrections $d\epsilon$, de', $e'd\pi'$ are small, and since the first of these has a small coefficient in the α-equations and de', $e'd\pi'$ have small coefficients in the δ-equations, the solution of the system of equations can be broken up into two separate solutions, with three unknowns in each:

α-equations, $\qquad c = \Delta\alpha_0 + dl',\ de',\ e'd\pi',$

δ-equations, $\qquad \Delta\delta_0,\quad d\epsilon,\quad dl'.$

The combination $c = \Delta\alpha_0 + dl'$, which may be considered to represent the apparent correction to the right ascension of the Sun relative to the assumed right ascensions of the clock stars, is introduced because the coefficient of dl' in the α-equations is so near unity that a separate determination of the unknowns $\Delta\alpha_0$ and dl' from the α-equations alone is impossible.

In a similar way one may consider the observation equations in right ascension and declination of a planet. In this case, however, the computed geocentric coordinates of the planet depend on both the geocentric coordinates of the Sun and the heliocentric coordinates of the planet. The observation equations will, therefore, contain in addition to the six unknowns (A) six corrections to the elements of the planet's orbit which may be called dc_i, $i = 1 \ldots 6$. A possible set would be:

$$dl,\ dn,\ de,\ ed\Pi,\ dJ,\ \sin J\ dN, \tag{B}$$

where J and N are the inclination of the orbital plane with the equator and the longitude of the ascending node on the equator, and Π the longitude of the perihelion counted along the equator to the ascending node of the orbit on the equator, and from this node to the perihelion.

In applying this method of solution to more than one planet simultaneously some modification of procedure may be desirable. The unknowns of set (A) occur in the equations for all planets, whereas the unknowns (B) are different in the case of each planet. A satis-

factory procedure would be, therefore, to transfer the unknowns (A) to the right-hand member, and to obtain from the solution the correction to the orbital elements of the planets as the sum of an absolute term and six terms containing the corrections (A), namely,

$$c_i = c_{i,0} + c_{i,1}\,\Delta\alpha_0 + c_{i,2}\,\Delta\delta_0 + c_{i,3}\,d\epsilon + c_{i,4}\,dl' + c_{i,5}\,de' + c_{i,6}\,e'd\pi'.$$

Substitution into the observation equations for all the planets will then produce equations with the unknowns (A), which can be obtained in one solution from all observation equations of all planets combined.

From the point of view of the determination of systematic corrections to star positions the corrections to the orbital elements are of only intermediary significance; the final results may be considered to be the values $\Delta\alpha_0$, $\Delta\delta_0$, and the residuals obtained by substitution of the final solution into the observation equations. A study of the distribution of the residuals over the regions of the sky covered by the observations will yield a possible solution for the systematic corrections to the star positions of the fundamental system to which the observed positions have been reduced for the mean epoch of the observing program.

If the method of least squares is used, the solution is that for which the sum of the squares of the deviations of the derived values for the corrections to the right ascensions and declinations from constants, $-\Delta\alpha_0$, $-\Delta\delta_0$, is a minimum. This is not necessarily the true solution. However, the procedure recommends itself by its simplicity, and it seems that this should be the first step toward the definitive solution.

An alternative procedure would be to introduce formally, instead of $\Delta\alpha_0$, $\Delta\delta_0$, the expressions

$$-\Delta\alpha_0 = a_0 + a_1 \cos\alpha + b_1 \sin\alpha + a_2 \cos 2\alpha + b_2 \sin 2\alpha,$$

$$-\Delta\delta_0 = a_0' + a_1' \cos\alpha + b_1' \sin\alpha + a_2' \cos 2\alpha + b_2' \sin 2\alpha,$$

the coefficients a_i, b_i, a_i', b_i' being unknowns, to be determined by the solution. One may even consider introducing different sets of unknowns for different zones of declination. The obvious objection to this form of solution is that too many unknowns would cause excessive complications, and might produce results of no real significance. It is useful in a general analysis of the problem to consider, at least theoretically, this representation of $\Delta\alpha_0$, $\Delta\delta_0$. Such considerations should be used in deciding upon the nature of the further approximations to the definitive solution.

The procedure outlined in the preceding sections can be followed in the discussion of observations of planets made with meridian circles and of observations made differentially with an equatorial telescope. The essential difference between the two classes of observations is that with a meridian circle it is possible to derive absolute declinations; owing to the rotation of the Earth the optical axis of the instrument traces on the celestial sphere parallels of declination.

DISCUSSION OF AN INDETERMINATENESS

In the case of purely differential meridian circle observations, and more especially, in that of observations with a photographic equatorial, no use is made of the rotation of the Earth. In fact, the last trace of this, namely the parallax, is eliminated in the comparison of the observations with ephemeris positions. It is thus evident that there is no possibility of tracing the equator among the stars from differential photographic observations of planets.

As a simplified model, one may consider observations of a planet as fixing the direction of the line joining one point, the center of the Earth, with another point, the center of the planet. Both points move on ellipses in their own orbital planes. The observations will determine these two orbital planes, namely, the ecliptic and the planet's orbital plane. The fact that the motions satisfy the equations of elliptic motion provides the possibility of measuring arcs in the sky.

The equatorial system of coordinates is merely of intermediate significance in the case of differential observations. It would, in fact, be simpler in many respects if the observations were made in an ecliptic system of coordinates of reference stars. In practice, one assumes for the equator a great circle among the stars that agrees as nearly as may be with the curve $\delta = 0$, as inferred from the star positions of the fundamental catalogue at the epoch of observation. In work on minor planets it is convenient to use the standard equinox and equator of 1950.0. The right ascensions of the catalog determine on this great circle a zero-point, the equinox of the catalog for 1950.0. The fundamental catalog thus defines a rectangular equatorial coordinate system XYZ among the stars. Suppose now that, in order to obtain the true equatorial system, rotations $d\omega_1$ about the X-axis, $d\omega_2$ about the Y-axis, and $d\omega_3$ about the Z-axis are required. These rotations produce the following corrections:

to the right ascensions of equatorial stars:

$$E = d\alpha = + d\omega_2 \cot \epsilon - d\omega_3,$$

to the declinations of equatorial stars:

$$d\delta = - d\omega_1 \sin \alpha + d\omega_2 \cos \alpha,$$

to the obliquity of the ecliptic:

$$d\epsilon = - d\omega_1.$$

Let the corrections that should be applied to the star positions of the fundamental catalog near the equator be

$$d\alpha = a_0 + a_1 \cos \alpha + b_1 \sin \alpha + a_2 \cos 2\alpha + b_2 \sin 2\alpha,$$
$$d\delta = a_0' + a_1' \cos \alpha + b_1' \sin \alpha + a_2' \cos 2\alpha + b_2' \sin 2\alpha.$$

The impossibility of determining the plane of the equator from differential observations is equivalent to indeterminateness of the rotations $d\omega_1$, $d\omega_2$. These rotations produce in $d\delta$ terms of the form $a_1' \cos \alpha + b_1' \sin \alpha$. Such terms, therefore, cannot be obtained from the solution. Assume that the solution is made by ignoring a_1', b_1'. The equinox correction so obtained will require the correction $+ a_1' \cot \epsilon$, and the obliquity of the ecliptic the correction $+ b_1'$. The coefficients $a_1' = + d\omega_2$, $b_1' = - d\omega_1$ can be obtained from meridian circle observations only.

There does not appear to exist any further indeterminateness of this nature. Numerov's[12] numerical test indicates a satisfactory determinateness of the coefficients a_1, b_1, in $d\alpha$. This test also gave a numerical indication of the indeterminateness of the coefficients a_1', b_1'. He made an attempt at an algebraic analysis of the problem a few years later.[13] Unfortunately the algebraic treatment leads to complicated relations whose interpretation is difficult.

The limitation of the determinable systematic corrections to star positions is not as serious as may be thought at first sight. Differential planetary observations do determine the plane of the ecliptic among the stars, and may fix an arbitrary zero-point for counting longitudes in the ecliptic by the nodes and perihelia of planetary orbits. The relation between such an arbitrary zero-point and the equinox remains unknown. The laws of motion permit the absolute measurement of arcs in the sky. Therefore, differential planetary observations enable us to determine absolute ecliptic coordinates of

[12] Bull. Inst Astr. Leningrad No. 32. 1932.
[13] Astr Nachr. No. 6234. 1936.

star positions. With a view to the ultimate purpose this is equally satisfactory as an absolute determination of equatorial coordinates.

This ultimate purpose is the determination of systematic corrections to proper motions, rather than to star positions at one epoch. This requires a second determination at a distant epoch, say, a repetition of a similar program forty or fifty years in the future. It may not be necessary to wait so long before making some progress. Perhaps much information is latent in the numerous scattered observations of minor planets during the past one hundred and forty years. The latter approach should at least be given a trial.

The determination of absolute proper motions necessarily requires a dynamical evaluation of the secular motions of the ecliptic, and of the orbital planes and the perihelia of the planets. It is the same problem as that treated by Anding,[14] Bauschinger,[15] and others for the four inner planets on the basis of Newcomb's results. In the case of the principal planets the determination is weak on account of the small inclinations and small eccentricities. Minor planets, especially those with large inclinations and large eccentricities, are more favorable.

Two essential questions remain. Are the planetary masses known or can they be determined with sufficient accuracy to permit the dynamical determination of the secular motions with the required precision? May the theory be assumed to give the correct secular motions?

For a long time contradictory results were obtained for the mass of Venus, and this produced a serious uncertainty in the theoretical motion of the ecliptic. This question has recently been brought close to a satisfactory solution by Clemence and Scott.[16] As a whole there appears to be satisfactory agreement between the observed and the theoretical values for the secular variations of the four inner planets. There is, therefore, every reason to expect that the same will also apply to the secular variations of the minor planets.

SEPARATION OF THE CORRECTIONS TO THE ORBITAL ELEMENTS

The corrections to the elements of the planetary orbits and to those of the Earth's orbit enter as unknowns of an intermediate nature in the solution of the problem. A question to be considered is whether

[14] Enc. Math. Wiss. 6 (2A): 13.
[15] Enc. Math Wiss 6 (2A): 889
[16] Publ A.A.S 10: 121. 1941.

these unknowns can be obtained with sufficient weight. As is well-known, a minimum of four oppositions is required for a proper determination of the six elements of an orbit. In a ten-year program the number of oppositions of a minor planet is seven or eight. Yet, even from such a series of observations, the mean motion of the planet may not be sufficiently separated from the other unknowns. In order to strengthen the solution it is our intention to continue the program for two or three oppositions beyond 1945, taking only a sufficient number of plates in the neighborhood of the date of opposition to secure a single strong normal. Also, it is our plan to collect miscellaneous published observations prior to 1935, and as far back as 1924, to furnish a few normals for these earlier years. The latter will have relatively low weight, but, on account of the large coefficient of the correction to the mean motion, they will strengthen the determination of this unknown.

Two unknowns that are notoriously poorly separated if the observations of a planet are limited to times near opposition are the correction to mean longitude of the Sun and that to the mean longitude of the planet. This problem has been discussed by Numerov.[17] Ross[18] experienced this difficulty in his discussion of observations of Mars.

The only way to arrive at a proper separation of these unknowns is to have the observations extend from well before to well after the date of opposition. In most cases the practical limits are from four months before to four months after opposition; in each specific case the limits are affected by season and declination.

Suppose that N observations are uniformly distributed in time from three months before to three months after opposition. From an average opposition of two planets on the program, the following weights are obtained if dl, dl' are the only unknowns considered.

	(12) Victoria	(57) Mnemosyne
weight of dl	$0.29\ N$	$0.22\ N$
" " dl'	$0.032N$	$0.014N$

A linear combination of dl and dl' can be determined with excellent weight; namely,

weight of $dl - \frac{n}{n'} dl'$	$2.0\ N$	$1.6\ N$

the weight of dl' remaining the same.

17 Astr. Jour. No. 1047. 1936

18 Astr. Pap. Am. Eph 9 (11).

Notwithstanding the low weight with which the correction to the Sun's mean longitude is determined from a single opposition of a minor planet, since this unknown occurs in the observation equations of all planets, the total weight of this unknown as obtained from the entire program may yet correspond to a significant determination. However, an accurate determination of this unknown is not an essential requirement. The weight is greater for planets with smaller semi-major axes, and less for planets with greater semi-major axes. On this account the planet Eros will be particularly valuable. The two planets for which the approximate weights are here given are, with the exception of Eros, the nearest one and the most distant one on the program.

The linear combination of dl and dl' chosen is $dl - \frac{n}{n'} dl'$. This combination is determined with almost the maximum weight. The advantage of the use of this unknown is that this linear combination of dl and dl' will remain constant even if, owing to changes in the rate of rotation of the Earth, the corrections to the mean longitudes of the Sun and of the planets should change proportionately to their mean motions.

So far in this discussion it has been assumed that the orbits of the Earth and of minor planets are fixed ellipses in fixed orbital planes. The addition of perturbations does not introduce essential complications. The rectangular equatorial coordinates of the Sun, referred to the equator and equinox of 1950.0, and published in the annual volumes of the national ephemerides are satisfactory for computing geocentric coordinates of minor planets with the exception of Eros at close approaches to the Earth. The minimum distance of the other minor planets on the program is in no case much less than one astronomical unit. Since the correction to the elements of the Earth's orbit are included among the unknowns to be determined from the observation equations, it was decided not to apply corrections to the Sun's rectangular coordinates.

COMPUTATIONS OF THE ORBITS

For the minor planets rectangular coordinates have been computed by numerical integration. Cowell's method is used, and all the definitive integrations are made with the Hollerith Machines of the Thomas J. Watson Astronomical Computing Bureau at Columbia University. The method has been explained in detail by Dr. W. J.

Eckert.[19] An interval of ten days is used, and the computations are made to the ninth decimal place in astronomical units. This method of machine integration makes possible the handling of such large computations as are required for this program. It was, indeed, fortunate that Dr. Eckert had just developed this method at the time when the program was undertaken. Otherwise, the amount of computation might have appeared too formidable.

Many of the orbits were known only with large uncertainties, and a great amount of work was required before sufficiently accurate orbits, even for search ephemerides, had been obtained.

At the present stage of the work numerical integrations for most of the planets on the program have been completed for the years 1932 to 1948. So far (433) Eros has been omitted. The work on four other planets is still in progress. The integrations are now being extended backward to 1924. At that stage we shall have fairly accurate orbits, covering about 24 years, and representing the geocentric positions of the planets within a few minutes of arc. These orbits have been computed with planetary perturbations that were obtained with approximate rectangular coordinates. The next step will be to make orbit corrections by comparison with observations, *i. e.*, a selection of scattered observations made between 1924 and 1935, and as many oppositions of our own program as are available. A new integration will then be made with improved starting values and exact perturbations. It is expected that in all but one or two cases these new orbits will satisfy all requirements for the final comparison with observations.

Possible sources of inaccuracy in these orbits need special attention. They are: uncertainties in planetary masses, the omission of the individual attraction by Mercury, and the effect of rounding off errors in the numerical integrations.

Since only perturbations of relatively short periods need be considered, there will be few terms with sufficiently large coefficients to be affected by a change in planetary masses. This point may be dealt with either by an approximate general theory, or by the method of special perturbations. In the case of Mercury general perturbations may be obtained. The principal effects are due to the indirect term in the disturbing function. These questions have not yet been examined fully. It is my guess that they are not of vital importance to the essential problem that concerns us. If they were ignored completely I would expect that the effects upon the individual planets

[19] Punched Card Methods in Scientific Computation 1940.

would practically cancel each other in the end, and that only a slight increase in the probable errors would result.

The question of the accumulation of errors in numerical integration is one of considerable interest in this work. I found[20] that the only serious accumulation is in the mean longitude, and that the error produced after n steps of integration has a mean value, in radians, and in units of the last decimal place,

$$\frac{1}{2a} n^{\frac{3}{2}}.$$

In the present case the unit is 10^{-9} radians $= 2 \times 10^{-4}$ seconds of arc. Since the mean date of the observations will be about 1940, we shall have, by backward and forward integration, for an average asteroid with $a = 2.75$:

1940 to 1924	$n = 584$	mean error 0″.51	(in 1924)
1940 to 1948	$n = 292$	" " 0 .18	(in 1948)

The resulting mean errors appear somewhat larger than may be tolerated. However, the orbit correction will absorb part of the errors, and the accuracy may, in fact, be entirely acceptable. Some modification in the method may be introduced for the final integrations in order to diminish the amount of accumulation. Several devices are available; experiments are being considered to decide upon the most suitable method.

METHOD OF REDUCTION OF THE OBSERVATIONS

The most direct method of reduction, namely the measurement on a short-focus plate of asteroid and General Catalogue stars had to be rejected for two reasons: first, the great difference in magnitude between the GC stars and some asteroids, especially when far away from opposition; second, the large probable errors of the GC stars if brought up to the present time.

Instead it was decided to use the AG stars as intermediate stars. For these stars recent photographic positions are now available in some declinations, and will be available in all declinations between $+30°$ and $-30°$ at the completion of the program.

If the telescope is powerful enough to show the faintest asteroids, a direct measurement of the asteroid with respect to the AG stars is

[20] Astr. Jour. No. 1072. 1937.

the most satisfactory method. This procedure is followed at Leiden, where an excellent set of observations has been secured with a photographic telescope with aperture 13 inches and focal length 17 feet.

A more complicated procedure is followed at Johannesburg and at Allegheny and New Haven. On account of their small field the long-focus telescopes at Johannesburg and at Allegheny show, as a rule, fewer than three AG stars. The five-inch Ross cameras at Johannesburg and at New Haven are not fast enough to show the fainter asteroids. By a combination of a long-focus telescope and a short-focus camera satisfactory results are obtained.

At Johannesburg the Ross camera is mounted on the tube of the long-focus telescope. There the field plate, *i. e.*, the plate taken with the short-focus camera, is secured simultaneously with the long-focus plate on which the asteroid shows. At New Haven are obtained the field-plates required for the reduction of the long-focus plates secured at Allegheny Observatory. Many of these plates are taken afterwards, sometimes a year after the date of the Allegheny plate for which it is to serve. In all cases the hour angles at Allegheny and New Haven are the same within narrow limits.

The procedure is then to measure on the long-focus plate the asteroid and a minimum of three, but usually four, faint comparison stars of eleventh magnitude approximately. These stars are just bright enough to show good measurable images on the field plate. They are measured on the field plate, together with five or six AG stars.

The asteroid position on the long-focus plate is then transferred to the field plate as follows: Let the coordinates of the comparison stars on the long-focus plate be X_j, Y_j, and on the field plate x_j, y_j. Let the asteroid's coordinates on the long-focus plate be X_A, Y_A. Choose dependences D_j such that, on the long-focus plate

$$X_A = [D_jX_j],\ Y_A = [D_jY_j].$$

If the plate showing the asteroid has the same center as the field plate, the rectangular coordinates of the asteroid transferred to the field plate will be:

$$x_A = [D_jx_j],\ y_A = [D_jy_j].$$

Call this the fictitious asteroid position on the field plate. Now select AG stars, with rectangular coordinates x_i, y_i, and choose dependences D_i, such that

$$x_A = [D_ix_i],\ y_A = [D_iy_i].$$

This refers the asteroid position to the AG stars on the field plate.

Actually the dependences do not have to be exact. As a rule we take two or three exposures on the long-focus plate, and two exposures on the camera plate. On account of the motion of the asteroid it would be necessary to use a different set of dependences for each exposure. This is actually the method used at Leiden, and it has some advantages. Our procedure is to use approximate dependences, and to obtain the offset: say

$$X_A = [D_s X_s] + N_x,$$

$$Y_A = [D_s Y_s] + N_y.$$

This requires fairly accurate orientation of the plates. As a rule, however, the error of orientation is small and the offsets are kept quite small. Those cases that have been examined in detail show no errors greater than 0″.03 due to this cause.

The same field plate sometimes serves for the measurement of two or even three long-focus plates. We permit an angle up to about 1° between the centers of field plate and long-focus plate. This angle causes correction terms in the fictitious position of the asteroid on the field plate. They are of the same nature as the tilt terms in the reduction of photographic plates, and can be easily applied. Namely, if X_c, Y_c are the coordinates of the plate center, and

$$S = (X_A - X_c)^2 - [D_s(X_s - X_c)^2],$$

$$T = (X_A - X_c)\ (Y_A - Y_c) - [D_s(X_s - X_c)(Y_s - Y_c)],$$

$$U = (Y_A - Y_c)^2 - [D_s(Y_s - Y_c)^2],$$

there are correction terms

$$pS + qT \text{ in } x_A, \qquad pT + qU \text{ in } y_A.$$

where p, q are the components of the angle between the centers of the two plates.

The transformation to right ascension and declination is made by Schlesinger's method.[21] Requirements of our program made it desirable to modify the method in details. Instead of obtaining corrections to the second order only, it was necessary to include third order corrections in practically all cases, and fourth order terms whenever the distances of stars from the center exceeded 50 mm. in either coordinate. Next, it appeared simpler to express the correction terms in the differences between the rectangular coordinates of the measured object and the plate center, rather than in terms of the difference in

[21] Astr Jour. No 874. 1926.

α and δ. The reduction is somewhat involved. Construction of auxiliary tables for the third and fourth order terms has been undertaken but has not yet been completed. The inconvenience is that the corrections depend on the declination of the center and that therefore different tables for different declinations must be computed.

ESTIMATE OF THE ACCURACY OF THE OBSERVATION

In order to estimate the probable error of asteroid positions so obtained, assume that on a field plate six AG stars are measured, and let the catalog probable error be ϵ_1 in each coordinate, and the probable error of measurement ϵ_0. Suppose there are four comparison stars in common between the long-focus and field plate, and let the probable error of measurement of these stars on the field plate be ϵ_0, and on the long-focus plate E_0. Let the asteroid be measured on the long-focus plate with probable error E_0. With the dependences D_j, D_i as introduced above one obtains for the probable error of the asteroid, ϵ,

$$\epsilon^2 = \epsilon_1^2\ [D_i^2] + \epsilon_0^2\ [D_i^2 + D_j^2] + E_0^2\ (1 + [D_j^2]).$$

With $\epsilon_1 = 0''.15$, $\epsilon_0 = 0''.15$, $E_0 = 0''.05$, and on the assumption of an ideal distribution of stars, such that all $D_i = 1/6$, all $D_j = 1/4$, and thus $[D_i^2] = 1/6$, $[D_j^2] = 1/4$, the result is:

$$\epsilon = 0''.13.$$

If the asteroid is measured directly on the field plate, the expression is simplified, namely,

$$\epsilon^2 = \epsilon_0^2 + (\epsilon_0^2 + \epsilon_1^2)\ [D_i^2].$$

On the same assumptions the calculated probable error is

$$\epsilon = 0''.17.$$

One may conclude that the position of an asteroid obtained from a combination of long-focus plate and field plate has approximately twice the weight of a position obtained directly on a camera plate.

Only a few series of observations have so far been reduced completely with accurate orbits and accurate star positions. The most complete discussion was made of a series of observations of Ceres in the year 1936. In this series observations at Johannesburg and at Allegheny were available. The probable errors obtained are of the same order as those computed in this section, but additional long series of both faint and bright asteroids must be discussed before a reliable determination of the average probable error can be made.

Plate Tilt and Differential Atmospheric Refraction

The plate tilt and the effect of differential atmospheric refraction must be taken into account in order to avoid systematic errors in the positions of asteroids.

The effect of plate tilt is negligible in the case of long-focus telescopes. At the Leiden Observatory Dr. van Herk has determined the effect of plate tilt by comparing positions obtained with the telescope east of the pier with positions obtained with the telescope west of the pier,[22] reversing the instrument between exposures, and has found the tilt effect negligible.

A similar procedure could be followed with the Ross-cameras. The adjustment of these cameras is left unchanged, but checked frequently by Schlesinger's optical procedure.[23] On a selection of plates a dozen AG stars are measured, of which eight are chosen as near the four corners as the measuring engine permits, and four near the center. Plate solutions which include quadratic terms are then made for the determination of the tilt.

The reason for this caution is that the error due to the neglect of plate tilt is systematic, and it is our aim to eliminate as completely as possible all systematic effects, even if their amount is only a few hundredths of a second of arc.

I discussed the effect of differential atmospheric refraction in the first outline of the program.[24] In order to be able to evaluate this effect we choose whenever possible AG stars of which the spectrum is known, and of which the spectral class is not earlier than A0 and not later than K5. Even for such large differences as between the zenith distance at Johannesburg, (latitude $-26°$), and Allegheny, (latitude $+40°$), the difference of the effect of atmospheric refraction is found to be small, and can be evaluated only after elimination of the tilt error.

[22] BAN 9: 163. 1940.
[23] Publ. Allegheny Obs 3: 59. 1914.
[24] Astr. Jour 1022 1935.

MEAN SECULAR PARALLAXES OF FAINT STARS

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INTRODUCTION

Cosmic distances are measured through reference to a characteristic of the cosmical object. The convenient characteristics are geometric or photometric, and thus the corresponding distances are measured relative to the observed value of a geometric segment or a photometric intensity. The distances may be expressed in absolute units if such can be done for the characteristic.

The geometric segment may be an inherent property of the system, for instance orbital motion, but the most useful characteristic is the parallactic one, *i. e.* the reflex caused on the object by a known motion of the origin of observation. Here we have two possible choices, the secular motion of the earth as a member of the solar system, which for all practical purposes is rectilinear for several centuries, or the annual motion of the earth, a periodic perturbation in the secular motion caused by the sun. The annual parallactic motion is easily distinguished from other effects, although orbital motion of the star may sometimes hamper immediate efforts at obtaining a value for the annual parallax. On the other hand the secular parallactic proper motion cannot be distinguished from the residual proper motion of the star, and the observed proper motion of a star is a resultant of the two.

It is clear that individual geometric distances can thus be obtained only by the annual parallax method. The results of modern photographic observations in this field are well-known.[1] Thousands of parallaxes have been obtained at several observatories with an accuracy expressed by a probable error of about 0″.01 for an individual determination, based on some 20 to 30 plates containing two or three exposures each. At present, attempts are being made to increase this accuracy by using a much larger number of plates; a probable error of 0″.003 has thus been reached for some stars. Such extended series of plates may also shed light on the problem of systematic errors by not limiting the observations to large parallax factors only.

The annual parallaxes are relative to a set of (usually 3 to 5) reference stars, whose probable mean parallax can be estimated from

[1] Schlesinger, Probleme der Astronomie, Seeliger Festschrift 422. 1924.

the mean secular parallaxes to be discussed later; in individual cases it may be desirable to determine spectroscopic parallaxes for the reference stars.

The modern determinations of annual parallaxes have thus given distance values with a probable error less than 10% for stars nearer than 10 parsecs. With an all-out effort the same percentage accuracy can be obtained for distances up to about 30 parsecs. Beyond this distance individual geometric distances become gradually more inaccurate although for statistical purposes distances up to 100 parsecs may be used. Here, therefore, the method of statistical proper motion parallaxes becomes important. In the present chapter the mean secular parallaxes will be studied, *i. e.* the secular parallactic motion will be considered as a distance criterion. From these parallaxes mean distances of groups of stars can then be derived if the solar velocity and the dispersion in distance are known. Closely related are mean parallaxes based on the total proper motion of the stars and on the component perpendicular to the parallactic motion, the so-called τ-components, which will be discussed by Emma Williams Vyssotsky elsewhere in this volume.

Considerable distance penetration is provided by the photometric method, since apparent magnitudes of very distant objects can be measured with adequate accuracy. The inherent complication of this method is the presence of obscuring material so that in reality only a relation between distance and opacity can be derived from the observed distance modulus:

$$m - M = 5 \log r + A - 5 \qquad (1)$$

Here m is the apparent magnitude, M the absolute magnitude, r the distance expressed in parsecs, and A the opacity in magnitudes between the observer and the object. If one combines this equation with a corresponding one in which A is ignored, a distance r' is found related to the true distance r as follows:

$$\log r' = \log r + 0.2\, A \qquad (2)$$

The quantity $\frac{r'}{r} = 1.58^{A}$ is the "opacity magnification" of photometric distances in which the opacity has been neglected.[2]

It is clear therefore that photometric distances alone cannot take us very far, although the opacity difficulty may often be tentatively circumvented by introducing some sort of geometric hypothesis. But a complete study of the fundamental properties of the galactic system

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[2] Sigma Xi Quart. 26: 103. 1938.

must comprise geometric methods; only in this way can a correct basis for galactic structure be obtained, which in combination with photometric data will then yield information about luminosity and absorption functions.

SOLAR MOTION; MEAN SECULAR PARALLAX

If we express the star's distance r in parsecs we have the following fundamental relations:

$$\text{Annual parallax} = \frac{1}{r}$$

$$\text{Secular parallax} = \frac{h}{r}$$

Here the parallax values are expressed in seconds of arc; h is the motion of the solar system expressed in astronomical units per year. If desired, a transition to absolute measure is given through the relation

$$1 \text{ A.U./year} = 4.74 \text{ km/sec.}$$

It is important to consider closely what is meant by *solar motion.* The convenient observational origin for stellar velocities is the sun. The only possible definition of solar motion in the galactic system is that it is the equal and opposite of the group motion of stars. The latter can be determined only if the stellar space velocities are known from proper motions, radial velocities and parallaxes.

The relation between rectangular and equatorial polar coordinates is

$$\begin{aligned} x &= r \cos\delta \cos\alpha \quad &&\text{where } +x \text{ points to the vernal equinox} \\ y &= r \cos\delta \sin\alpha &&\phantom{\text{where }} +y \text{ " " R.A. } 6^{\mathrm{h}} \text{ in equator} \\ z &= r \sin\delta &&\phantom{\text{where }} +z \text{ " " the celestial north pole} \end{aligned} \tag{3}$$

Here x, y, z, and r are expressed in parsecs.

The annual variations are given by

$$\begin{aligned} \dot{x} &= -r\cos\delta\sin\alpha\,\mu_\alpha - r\sin\delta\cos\alpha\,\mu_\delta + \cos\delta\cos\alpha\,\dot{r} \\ \dot{y} &= r\cos\delta\cos\alpha\,\mu_\alpha - r\sin\delta\sin\alpha\,\mu_\delta + \cos\delta\sin\alpha\,\dot{r} \\ \dot{z} &= \phantom{-r\cos\delta\cos\alpha\,\mu_\alpha -{}} r\cos\delta\,\mu_\delta + \sin\delta\,\dot{r} \end{aligned} \tag{4}$$

Here $\dot{x}$, $\dot{y}$, $\dot{z}$ and $\dot{r}$ are expressed in A.U./year; μ_α and μ_δ are the proper motion components expressed in seconds of arc per year.

For a certain group of stars therefore the group motion is given by the rectangular components $\bar{\dot{x}}$, $\bar{\dot{y}}$, $\bar{\dot{z}}$, the solar motion by the equal and opposite values h_x, h_y, h_z, so that

$$h_x = -\dot{x},\ h_y = -\dot{y},\ h_z = -\dot{z} \tag{5}$$

From this the solar velocity h and the right ascension A and declination D of the apex easily follow:

$$\begin{aligned} h &= \sqrt{h_x^2 + h_y^2 + h_z^2} \\ \tan A &= \frac{h_y}{h_x} \\ \tan D &= \frac{h_z}{\sqrt{h_x^2 + h_y^2}}. \end{aligned} \tag{6}$$

The parallactic parts of the velocity components of the individual stars are given by

$$\begin{aligned} \mu_{\alpha,p} \cos\delta &= \frac{h_x}{r}\sin\alpha - \frac{h_y}{r}\cos\alpha \\ \mu_{\delta,p} &= \frac{h_x}{r}\cos\alpha\sin\delta + \frac{h_y}{r}\sin\alpha\sin\delta - \frac{h_z}{r}\cos\delta \\ -\dot{r}_p &= h_x\cos\alpha\cos\delta + h_y\sin\alpha\cos\delta + h_z\sin\delta. \end{aligned} \tag{7}$$

Here $\frac{h_x}{r}$, $\frac{h_y}{r}$ and $\frac{h_z}{r}$ are the rectangular components of the secular parallax $\frac{h}{r}$ and shall be denoted by X, Y, Z. If also we express the third equation in absolute units, we obtain the commonly used formulae for the polar components of parallactic motion:

$$\begin{aligned} &\text{(a)} \quad \mu_{\alpha,p}\cos\delta = X\sin\alpha - Y\cos\alpha \\ &\text{(b)} \quad \mu_{\delta,p} = X\cos\alpha\sin\delta + Y\sin\alpha\sin\delta - Z\cos\delta \\ &\text{(c)} \quad -V_p = V_x\cos\alpha\cos\delta + V_y\sin\alpha\cos\delta + V_z\sin\delta. \end{aligned} \tag{8}$$

The problem of secular parallax becomes important only for the case of stars whose individual distances are unknown or not regarded. Assuming now that for a group of stars in a limited portion of the sky the residual proper motions cancel with respect to their mean parallactic motion, the mean proper motion gives the following equations:

$$\begin{aligned} &\text{(a)} \quad \overline{\mu_\alpha \cos\delta} = X\sin\alpha - Y\cos\alpha \\ &\text{(b)} \quad \overline{\mu_\delta} = X\cos\alpha\sin\delta + Y\sin\alpha\sin\delta - Z\cos\delta \end{aligned} \tag{9}$$

where X, Y, and Z now represent the rectangular coordinates of the *mean* secular parallax of the stars.

A number of groups of stars well distributed over the sky furnish a number of pairs of equations of conditions (9); a least-squares solution gives values of X, Y, and Z. Their relation to the mean secular parallax and the position of the apex is then given by

$$
(10)\quad
\begin{aligned}
X &= h\,\overline{\left(\frac{1}{r}\right)} \cos A \cos D & \qquad h\,\overline{\left(\frac{1}{r}\right)} &= \sqrt{X^2 + Y^2 + Z^2} \\
Y &= h\,\overline{\left(\frac{1}{r}\right)} \sin A \cos D & \tan A &= \frac{Y}{X} \\
Z &= h\,\overline{\left(\frac{1}{r}\right)} \sin D & \tan D &= \frac{Z}{\sqrt{X^2 + Y^2}}\,.
\end{aligned}
$$

If only radial velocities are known formula (8c) can be used on the assumption that the residual radial velocities cancel. In that case a least-squares solution gives values for the rectangular components V_x, V_y, V_z of the solar velocity V_0 and we have:

$$
(11)\quad
\begin{aligned}
V_x &= V_0 \cos A \cos D & \qquad V_0 &= \sqrt{V_x^2 + V_y^2 + V_z^2} \\
V_y &= V_0 \sin A \cos D & \tan A &= \frac{V_y}{V_x} \\
V_z &= V_0 \sin D & \tan D &= \frac{V_z}{\sqrt{V_x^2 + V_y^2}}\,.
\end{aligned}
$$

Either solution (10) or (11) is based on the assumption that the solar motion is sufficiently exhibited by either the transverse or radial components of the space motions. Formula (10) therefore enables us to obtain the mean secular parallax and solar apex for a group of stars whose proper motions are known; formula (11) gives us the solar velocity and solar apex for a group of stars whose radial velocities are known; either method thus yields an apex determination.

In order to obtain the three rectangular components of the solar motion, any systematic effects must, of course, be properly taken into account. In the case of radial velocities, possible redshift will have to be considered; in the case of proper motions, precession corrections may be in order. In either case the effects of differential galactic rotation are present. Systematic errors of observational origin are of serious consequence especially in the case of small proper motions. In the next sections the various significant effects will be further discussed for the case of proper motions.

For the sake of completeness the formulae are given for deriving mean secular parallax and solar velocity in case the apex is considered

as known. If we introduce λ, the angle between the star and the antapex, the parallactic components of the total proper motion and of the radial velocity are given by

$$(12)\qquad \text{(a)}\quad \mu_p = \frac{h}{r}\sin\lambda$$

$$\text{(b)}\quad V_p = V_0 \cos\lambda.$$

Again on the assumption that the residual motions of the stars cancel, the quantity μ_p is given by the component of proper motion toward the apex, the so-called v-component; similarly V_p is set equal to the observed radial velocity V. (The v-component is derived from the total proper motion μ and its position angle θ by the relation

$$v = \mu \cos(\theta - \chi)$$

where χ is the position angle of the antapex).

In this case, therefore, the least-squares solution leads to the following simple expressions for mean secular parallax and solar velocity:

$$(13)\qquad \text{(a)}\quad h\overline{\left(\frac{1}{r}\right)} = \frac{[v\sin\lambda]}{[\sin^2\lambda]}$$

$$\text{(b)}\quad V_0 = \frac{[V\cos\lambda]}{[\cos^2\lambda]}.$$

If thus for a group of stars $h\overline{\left(\frac{1}{r}\right)}$ can be obtained, the value of $\overline{\left(\frac{1}{r}\right)}$ can be derived if the sun's velocity h is known. With adequate knowledge about the dispersion in r the mean parallax $\overline{\left(\frac{1}{r}\right)}$ can then be converted into a value for the mean distance $\bar{r}$. This question will be taken up later on.

It is clear that the secular parallax method will be most successful if the residual motions are small compared with the mean parallax. It is further obvious that regions near the apex and antapex have greatest weight in determining the direction of solar motion while those 90° from the apex have highest weight in the determination of mean secular parallax. An inherent weakness of the parallactic motion method of deriving mean parallaxes is therefore the lack of equivalence in accuracy between different parts of the sky. Since the solar apex lies not far from the galactic circle, the secular parallax factors and hence the parallactic motions are large in high galactic latitudes but relatively small in lower latitudes. A determination of mean

secular parallaxes in low latitude has, therefore, other things being equal, less accuracy than one in high latitudes, and is also more sensitive to uncertainties in the reference system of proper motions.

PROPER MOTIONS: REFERENCE SYSTEM FOR LIMITED AREA

As stated before, the problem of mean secular parallaxes is primarily of importance for stars beyond the limit of annual parallax observation, *i. e.*, for stars with an annual parallax of less than say ″.03. For a solar velocity of 4 A.U./year, the corresponding upper limit of parallactic motion at the parallactic equator is ″.12. In proper motion work this is a large quantity and the usefulness of the method is thus clearly demonstrated.

In studying the attainable accuracy of mean secular parallaxes, it is especially necessary to know the limitations due to uncertainties in the system of reference, which are both of cosmical and observational origin. It is necessary, therefore, to discuss these sources of errors for the basic material, *i. e.*, proper motions. By cosmical errors are meant the deviations of the proper motions of individual stars or groups of stars from an adopted theoretical motion.

Proper motions may be measured with meridian circle, visual refractor (micrometer, heliometer), or by photography. In the latter case, which is very important because of its high accuracy, the proper motions are measured in any rectangular coordinate system, however, the one that is oriented closely to the equatorial system being most convenient. The results thus obtained are directly comparable with proper motion components measured with the meridian circle. The orientation of the equatorial coordinate system is found from stars of known absolute position if they occur in the region, or by a trail. For the simple case of linear plate constants the measured differences m_x, m_y between the positions on two plates taken at different epochs are:

$$\begin{aligned} m_x &= t\mu_x + c_x + a_x x + b_x y + \delta_x \\ m_y &= t\mu_y + c_y + a_y x + b_y y + \delta_y \end{aligned} \tag{14}$$

Here t is the interval; μ_x, μ_y is the yearly proper motion and is practically equal to $\mu_\alpha \cos\delta$, μ_δ. The quantities c_x, a_x, b_x, c_y, a_y, b_y are the plate constants expressing differences in orientation and scale and the first order effects of precession, nutation, aberration, refraction; δ_x and δ_y are accidental errors of observation. By using gratings, magnitude compensation is easily provided, thus minimizing an important

source of systematic error. In case of large areas or large zenith distances, higher order terms may have to be included, which does not essentially alter the problem.

The ideal way of determining the plate constants would be from extragalactic objects, which form an ideal frame of reference for proper motions of (inter)galactic objects. There is little doubt that eventually all present reduction methods will become subordinate to the one provided by extragalactic objects. But for sometime to come the extragalactic reference system is not likely to reach a stage of practical application and we shall have to use an intergalactic reference system based on stars. Within the restricted area covered by a photographic plate a kind of internal system can always be obtained by deriving the plate constants from the stars themselves. For this purpose we consider the proper motions (μ_x, μ_y) as accidental deviations from the average reference system provided by the stars; the plate constants are then simply obtained from the conditional equations

$$\begin{aligned} m_x &= c_x + a_x x + b_x y \\ m_y &= c_y + a_y x + b_y y \end{aligned} \qquad (15)$$

The probable error of one equation is in each coordinate given by

$$R = 0\ 6745 \sqrt{\frac{t^2\,[\mu^2] + [\delta^2]}{n-3}} \qquad (16)$$

The probable errors of the plate constants a and b are given by

$$r_a = \frac{R}{\sqrt{p_a}}, r_b = \frac{R}{\sqrt{p_b}}$$

where p_a and p_b are the weights of a and b.

In this way proper motions are obtained relative to the origin of an internal reference system represented by a plate constant structure (c, a, b) in each coordinate. This reference system suffers a (linear) distortion term $(x\epsilon_a + y\epsilon_b)$ which is of the nature of proper motion. Here ϵ_a and ϵ_b are the true errors of the plate constants a and b and are partly of cosmical origin. The motions referred to this reference system are thus affected by a systematic error — $(x\epsilon_a + y\epsilon_b)$, but we can only say that the plate constant structure introduces a probable error

$$\pm \sqrt{x^2\, r_a{}^2 + y^2\, r_b{}^2}$$

It is clear that no matter how small the errors of observation

(δ_x, δ_y), the accuracy of the proper motions is definitely limited by the distribution of the proper motions of the stars.

Apart from this the absolute proper motion of the reference system remains undefined, and thus proper motions derived in this manner are called *relative*. The part of the plate constants which is of cosmical origin, for the relative motions, finds a counterpart in the cosmical part of the precession constants which result from the same source, for the case of absolute motion; this matter will be considered in the last section.

PROPER MOTIONS: ABSOLUTE REFERENCE SYSTEM; PRECESSION, GALACTIC ROTATION, SYSTEMATIC ERRORS

For problems of limited areal extent (parallax, orbital motion, cluster motion), the afore described internal reference system is of great value. For a study of fundamental galactic properties a more comprehensive reference system is necessary. Pending the advent of the extragalactic reference system we must use the reference system of so-called *absolute positions* and *proper motions* measured in the equatorial coordinate system and referred to the sun, as established by our methods of observing positions on the celestial sphere.

The internal reference system referred to a moment ago can then be reduced to absolute if one or more stars with known absolute motion could also be measured in the limited area of the photographic plate. By using plates of large area a sufficient number of those reduction stars may also be included to compute all plate constants.

The instruments commonly used for measuring stellar positions are the transit and vertical circle, or a meridian circle which is a combination of a transit instrument and a vertical circle for measuring right ascensions and declinations, respectively, the first with a sidereal clock as an accessory. The right ascensions of stars are obtained by comparing the transits of stars and sun, the equinox is located by observing at the same time the declination of the sun. The declinations are determined from observations at upper and lower culmination corrected for refraction.

By comparing observations of R. A. and Decl. made at different epochs annual variations are derived. The secular part of these annual variations consists of (1) the proper motion of the star, (2) the effect of precession of the reference system, (3) errors of observation. It is clear that the reference system can again only be an internal one in the sense that it is defined by a limited number of stars

whose annual variations have been observed. The cosmical distribution of these motions is one of the factors limiting the attainable accuracy of the precessional constants. Again, the ideal way of determining the precessional corrections would be from the observed annual variations of extragalactic objects, a thoroughly impractical procedure however. It is interesting to reflect that, because of limitations of brightness, conventional meridian circle observations will not enable us to establish an extragalactic reference system. The latter may eventually be based on photographic observations, the meridian circle observations will then still play an important role in transferring the reference system to regions in the sky which are inadequately provided with extragalactic objects.

A system of absolute motions in a restricted sense can always be obtained by deriving the precessional corrections from the stars themselves. Assuming the observed annual variations to be corrected for an adopted precession (Newcomb's value for example), the resulting proper motions (+ systematic error) can be represented by the sum of the precessional corrections and any systematic motions that can be approximately expressed in analytical form, like galactic rotation and parallactic motion. The question of finding the precessional constants is thus intimately tied up with the cosmical laws governing stellar motions.

The first order (yearly) *precessional corrections* are

$$\begin{aligned} &\text{in right ascension} \quad \Delta m + \Delta n \sin\alpha \tan\delta \\ &\text{in declination} \quad \Delta n \cos\alpha \end{aligned} \tag{17}$$

where $\Delta m = \Delta p \cos\epsilon - \Delta l$

$\Delta n = \Delta p \sin\epsilon$

Here p is the lunisolar precession

l the planetary precession

ϵ the inclination of the ecliptic on the equator.

While Δl can be obtained from theoretical considerations (secular perturbations), Δp can be found only from a discussion of proper motions. In addition the proper motions in right ascension are usually considered to be affected by a constant error $-\Delta e$ called the "motion of the equinox." This is partly a linear time effect due to changes in observational technique, partly an error of cosmical origin, due to the distribution of the proper motions of the stars used in any particular solution for precessional corrections.

It goes without saying that an analysis for precessional corrections will obliterate any systematic stellar motion that would follow the same analytical law as the precession does. It is, therefore, to be noted that the equator and ecliptic are at an appreciable angle with the galactic circle. Luni-solar and planetary precession reveal themselves as a rotation of the stars about the pole of the ecliptic and the pole of the equator, respectively; any rotation of the galactic system may thus be separated from the precessional effects.

On the simple Oort theory, the *differential galactic rotation* effects in seconds of arc per year are in right ascension:[3]

$$2(A\cos 2\alpha + B\sin 2\alpha)\cos\delta + \{(C + .15Q)\sin\alpha + (D + .86Q)\cos\alpha\}\sin\delta + .46Q\cos\delta \quad (18)$$

in declination:

$$(B\cos 2\alpha - A\sin 2\alpha)\sin 2\delta + (D\sin\alpha - C\cos\alpha)\cos 2\delta + E\sin 2\delta - .86Q\sin\alpha + .15Q\cos\alpha \quad (19)$$

where

$$\begin{array}{llll} A = +.104P\sin 2l_0 & -0\,220P\cos 2l_0 \\ B = -.287 \quad " & -0.080 \quad " \\ C = -.409 \quad " & -0\,154 \quad " & & (20) \\ D = +.072 \quad " & -0.870 \quad " \\ E = +.585 \quad " \end{array}$$

Here l_0 is the galactic longitude of the center of rotation; P and Q are Oort's constants of differential galactic rotation expressed in seconds of arc per year, *i. e.*

$$P = \frac{1}{4\,74}\cdot\frac{1}{2}\left(\frac{V_0}{R} - \frac{\partial V_0}{\partial R}\right)$$
$$Q = \frac{1}{4.74}\;\frac{1}{2}\left(-\frac{V_0}{R} - \frac{\partial V_0}{\partial R}\right) \quad (21)$$

V_0 and R being the circular velocity in the vicinity of the sun in km./sec. and the distance to the axis of rotation expressed in parsecs. The numerical coefficients are trigonometric functions of the right ascension and declination of the galactic pole.

The Q-term in galactic longitude is really a combination of galactic rotation and the precession of the descending node of the equator on the Milky Way, as caused by the attraction of the stars on the planetary system. A computation by Axel Jönsson shows[4] that with

[3] Schilt, Astr Jour 39: 17 1928

[4] Charlier, "Motion and distribution of the stars" p 32 1926

any plausible assumption regarding the constitution of the galaxy this precession of the invariable plane turns out to be indirect. Hence the Q-term, which is direct, gives only a lower limit for the galactic rotation term.

Apart from the dependence of absolute proper motions on the precessional constants, a limitation to any progress in a study of absolute proper motions is caused by *systematic errors* in their reference system. The presence of systematic errors of a periodic nature is most serious, as solar motion, precession and galactic rotation contain first and second harmonics depending on right ascension and declination.

A striking example was given in 1922 by Kapteyn[5] who showed the possibility of considerable errors in the proper motions in declination of the PGC.[6] Kapteyn reasons that there is an a priori reason to believe that the correction Δ will be small near the poles, where the two culminations of a star are observed in nearly the same zenith distance. Systematic errors due to uncertainties in refraction would be likely to increase with increasing polar distance. Kapteyn adopts therefore $\Delta = G \cos \delta$, which gives a means of testing the presence or freedom of systematic errors in absolute proper motions by the methods and theories of stellar statistics. For an error $-G \cos \delta$ in proper motions in declination is equivalent to a system of proper motions diverging from the North Pole as an apex, in other words, the Z component of the parallactic motion is increased to $Z + G$. The result is a higher value of declination of the apex the amount depending on the values of G and the mean secular parallax. Now the declination of the apex found from the proper motions of the PGC is $+35°$, while that from the radial velocities of corresponding stars was only $+25°$. Kapteyn thus derives $G = +''.014$.

Subsequent investigations[7, 8, 9, 10] have tended to reduce Kapteyn's value and the error appears to be taken care of partly by corrections derived by Raymond.[11] There is however still an appreciable difference between the Albany General Catalogue in which Raymond's corrections have been incorporated and the FK3 fundamental system[12] in the sense that especially for small proper motions the apex in the former comes out at a very much larger declination.[13]

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5 Bull. Astr Inst, Netherlands 1: 75. 1922.
6 Boss, L., "Preliminary General Catalog of 6188 stars." 1910.
7 Bull. Astr. Inst. Netherlands 1: 209. 1923
8 Lick Obs. Bull 12: 38 1925.
9 Astr. Jour. 36: 138. 1926.
10 Bull Astr. Inst Netherlands 5: 1 1928.
11 Astr Jour. 36: 129. 1926.
12 Dritter Fundamentalkatalog Berliner Astr. Jahrb. Ver. Astr. Rechen-Insts Berlin Dahlem 54. 1937
13 Wilson & Raymond, Astr. Jour. 47: 49. 1938.

ANALYSIS OF PROPER MOTIONS FOR SOLAR MOTION, PRECESSION AND GALACTIC ROTATION

Summarizing the various contributing factors, the observed absolute proper motion of a star may thus be in general represented as follows; in right ascension (seconds of arc)

$$
\begin{aligned}
&2\,(A \cos 2\alpha + B \sin 2\alpha) \cos \delta + \\
&\quad \{(C + .15Q + .44\Delta p) \sin \alpha + (D + .86Q) \cos \alpha\} \sin \delta \qquad (22)\\
&\quad + (.46Q + .92\Delta p - \Delta e - \Delta l) \cos \delta + X \sin \alpha - Y \cos \alpha - \epsilon_\alpha;
\end{aligned}
$$

in declination

$$
\begin{aligned}
&(B \cos 2\alpha - A \sin 2\alpha) \sin 2\delta + \\
&\quad (D \sin \alpha - C \cos \alpha) \cos 2\delta + E \sin 2\delta - .86Q \sin \alpha + \qquad (23)\\
&\quad (.15Q + .44\Delta p) \cos \alpha + X \sin \delta \cos \alpha + Y \sin \delta \sin \alpha - Z \cos \delta - \epsilon_\delta,
\end{aligned}
$$

where ϵ_α and ϵ_δ are the residuals of the stars' actual motion from the analytical representation by mean parallactic motion, precession and galactic rotation.

From a material homogeneous enough to warrant a sufficiently constant $h\left(\frac{1}{r}\right)$ or one which is a simple analytical function of the position on the sphere, which does not conflict with the galactic rotation function, the various constants in the formulae can be derived if a sufficient number of stars is available. A least-squares solution will give the values for the following constants and combinations of constants,

from the right ascension equations:

$$
\begin{array}{lcll}
A & & P & \\
B & & l_0 & \\
C + 0.15Q + .44\Delta p & & Q & \\
D + 0.86Q & \text{whence} & \Delta p & (24)\\
0.46Q + 0.92\Delta p - (\Delta e + \Delta l) & & \Delta e + \Delta l & \\
X & & X & \\
Y & & Y &
\end{array}
$$

from the declination equations:

$$\begin{array}{lcl} A & & P \\ B & & l_0 \\ C & & Q \\ D & \text{whence} & \Delta p \\ E & & X \\ 0.86Q & & Y \\ 0.15Q + .44\Delta p & & Z \\ X & & \\ Y & & \\ Z & & \end{array} \qquad (25)$$

A combined solution would give all eight unknowns. However, separate solutions are of interest because of possible systematic errors in the proper motions which may affect the two coordinates quite differently. If we suppose, *e. g.*, with Schilt[3] that systematic errors are more likely to be periodic in a than in 2α, then the galactic rotation constants P and l_0 obtained from A, B and E are to be preferred to those obtained from C and D. It is clear therefore that truly independent determinations of precessional corrections, differential galactic rotation and solar motion should go always hand in hand. It is true that the constants P, l_0, A and D can often be obtained from radial velocity observation, the first, however, not without considerable systematic uncertainty. The accuracy with which the various constants in the equations can be determined depends on (1) number of objects, (2) uniformity of distribution over the sky, (3) cosmical accuracy of the proper motions, *i. e.*, the accuracy with which an individual star or group of stars represents the hypothesis of precession, differential galactic rotation and solar motion, (4) observational accuracy of the proper motions.

As far as precessional corrections, differential galactic rotation and systematic errors in the fundamental system are concerned, objects of high cosmical accuracy are most useful, *i. e.*, objects of small mean parallax.

AVAILABLE MATERIAL OF ABSOLUTE PROPER MOTIONS. RESULTS FOR MEAN SECULAR PARALLAX

The number of stars for which absolute proper motions can be derived directly has been limited by the size of the instrument which does not permit observations of stars fainter than magnitude 9 or 10.

However, with a sufficient number of "standard" stars to start with, it is possible to derive the absolute (positions and) proper motions of any additional number of fainter stars by the photographic method. As far as the positions are concerned, the development of thought on this subject may be seen from a digest of reports and discussions of commission No. 8 of the International Astronomical Union. The general opinion is that because of Schlesinger's success with plates of large areas meridian work may very well be limited to stars brighter than say 7.5 (of which there are 27,000) or than 8.0 (45,000). Stars of this magnitude are easily observable with most instruments. Since between 16 and 25 comparison stars are required for the reduction of each plate an extension to fainter magnitudes should be made in those regions of the sky where the number of brighter stars is not sufficient.

For the present we mean by "standard" stars those stars for which absolute proper motions have been derived from all available meridian circle positions. The Albany General Catalogue[14] is an example of a catalog containing the absolute proper motions of 33,342 stars, *i. e.*, all stars brighter than about magnitude seven and a half. The probable errors in this catalog are about 0″.001 for stars down to the fifth magnitude and about 0″.002 for the sixth magnitude stars, but much larger errors (as large as 0″.015) exist for the fainter stars, especially in the southern hemisphere. An extension of the system of a standard catalog like this to fainter objects can be made in different ways. One transfer is at present being carried out at Yale in several Astronomische Gesellschaft zones by Schlesinger's method of large angle photographs. In this manner proper motions of over 60,000 stars have already been obtained;[15] potentially the AG zones provide for deriving the proper motions of some 150,000 stars down to magnitude 9.7. The probable error of the proper motions averages about ″.010, which value would of course be greatly reduced by future repetition of the plates.

A very effective transfer from relative to absolute motions has been made for faint stars in small areas photographed with a long focus instrument and centered on a standard star whose magnitude equation can be fully eliminated through a rotating sector of similar device. The importance of this method for obtaining absolute motions was pointed out by Schlesinger[16] and again emphasized by Kapteyn.[5]

[14] "General Catalogue of 33342 stars" 1937.

[15] Trans. Yale Obs. 3. 1926; 4. 1925; 5. 1926; 7. 1930; 9. 1933, 10. 1934; 11. 1939, 12. 1940.

[16] Publ. All. Obs. 4: 19 1919.

The method has been further worked out and results were obtained first by Alden and van de Kamp[17, 18, 19, 20] and later by van de Kamp and Vyssotsky[21, 22]; the latter investigation which is of particular value for the problem of mean secular parallax will be fully discussed further on.

We shall now consider the present status of our knowledge of mean secular parallaxes of faint stars. An early discussion of mean secular parallaxes based on absolute proper motions of stars generally brighter than the tenth magnitude was made in 1918 by Kapteyn, van Rhyn and Weersma.[23] The solar apex was adopted at $A = 17^h51^m$, $D = +31°.4$ in accordance with Weersma's result;[24] the proper motions were reduced to the PGC system to which Boss' precessional corrections[6] were applied. For stars of all spectral types together it was found that the logarithm of the mean secular parallax was closely represented by a linear function of the magnitude:

$$\log h \left(\overline{\frac{1}{r}}\right) = a + bm, \qquad (26)$$

Gal. lat.	a	b
0 to ±20°	−0 519	− 1373
±20° to ±40°	− .477	− 1373
±40° to ±90°	− 389	− 1373

where m is the Harvard visual magnitude. Values of $h \left(\overline{\frac{1}{r}}\right)$ for the principal six spectral types B, A, F, G, K, M were derived also down to a somewhat brighter magnitude limit.

A few years later (1922) Kapteyn[5] published his paper on the proper motions of the faint stars and the systematic error of the Boss fundamental system. Kapteyn proposed a plan which was essentially that described above, namely the transfer of the Boss system to faint stars in the small areas surrounding bright stars which then already were on various parallax programs carried out with long focus instruments. The conditions at the McCormick Observatory were particularly favorable for such a plan, which was then

[17] Astr. Jour. 36: 17. 1924.
[18] Astr. Jour. 36: 190. 1926.
[19] Bull. Astr. Inst. Netherlands 3: 217. 1926.
[20] Mem. Nat. Acad. Scien 22, first memoir, pt. 3 (Publ. McCormick Obs. 4). 1927.
[21] Astr. Jour. 45: 161, 177. 1936; 46: 9, 25. 1937
[22] Publ. McCormick Obs 7. 1937.
[23] Groningen Publ. No. 29. 1918.
[24] Groningen Publ. No. 21. 1908.

taken up by Alden and the writer. It is of interest to note that the work, originally planned for a year, became a permanent feature of the McCormick program. At first, the mean proper motions of some half-dozen faint stars in the field surrounding a Boss star were utilized but no attempt was made to determine the individual motions. The first results published by Alden and van de Kamp[17, 18, 19, 20] in 1924 give a solar apex differing somewhat from that derived from bright stars and a stronger dependence of the mean secular parallax on galactic latitude than found in Groningen Publication No. 29.

After Alden's departure this proper motion work was first carried on by the writer, preference being given to regions in high galactic latitude. The additional measurements, together with an increased knowledge about the systematic error in the Boss proper motions in declination, led in 1927 to a new determination[25] of the mean secular parallax of tenth magnitude stars for different galactic latitudes. The mean secular parallax in high latitude, was found to be considerably larger than that derived in Groningen Publication No. 29, and given in table 26 of that publication. This became the main reason for a revision of the Groningen parallaxes by van Rhyn and Bok.[26] The newly discovered differential galactic rotation by Oort[27, 28] and the resulting changes in precessional corrections, as well as corrections[29] derived to the Boss proper motions in declination, were taken into account in their revision. Besides the earlier material, the McCormick material, some new results of zone-observations and some mean proper motions of thirteenth magnitude stars by van Maanen[30] had become available. In addition, differential values for $h\left(\overline{\frac{1}{r}}\right)$ were derived from relative photographic proper motions, some previously compiled and discussed by the writer,[31, 19, 32] and some from measurements by Lee[33, 34] and Smart.[35] It should be remarked that such material, especially in a limited number of regions is vulnerable to magnitude error since no magnitude compensation was present. Van Rhyn and Bok found

[25] Astr. Jour. 37: 191. 1927.
[26] Groningen Publ. No. 45. 1931.
[27] Bull. Astr. Inst. Netherlands 3: 275. 1927.
[28] Bull. Astr. Inst. Netherlands 4: 79. 1927.
[29] Boss & Jenkins, Astr. Jour. 37: 177. 1927.
[30] Pop. Astr. 32: 559. 1924.
[31] Publ Astr. Soc. Pac. 37: 276. 1925
[32] van de Kamp, De zonsbeweging met betrekking tot apparent zwakke sterren. 1926.
[33] Publ. Yerkes Obs 4, pt. 4. 1926.
[34] Bull. Astr. Neth. 5: 101. 1929.
[35] Cambridge Observations, 26. 1928.

again that the logarithm of the mean secular parallax could be represented as a linear function of the magnitude within each of the three galactic latitude zones, with the following constants:

Gal. lat.	a	b
0° to ±20°	−0.572	−.132
±20° to ±40°	−0 368	−.158
±40° to ±90°	−0 488	− 120

According to this, the values of the mean secular parallaxes of stars fainter than the eight magnitude are somewhat smaller in the zone ± 20° to ± 40° than the corresponding values in the zone 0° to ± 20°. van Rhyn and Bok considered this a priori rather improbable and decided to adopt the mean values of the zones 0° to ± 20° and ± 20° to ± 40° for stars fainter than magnitude 8 as valid for both zones. As compared with Groningen Publication 29 the secular parallaxes in the zones 0° to ± 20° and 20° ± 40° were reduced and the values in the zone ± 40° ± 90° were increased.

Except for an isolated observation at the 13th magnitude (van Maanen) and some material on relative photographic proper motions, van Rhyn and Bok had no material fainter than the 10th magnitude nor any means for studying the mean secular parallaxes of faint stars of different spectral classes.

McCORMICK INVESTIGATION. INTERPOLATION FORMULA FOR MEAN PARALLAX

Since 1926 Vyssotsky and the writer had been engaged in revising and extending the McCormick investigations started in 1922. Results of the extended investigation were published in the Astronomical Journal between 1935 and 1937, complete information being given in volume 7 of the Publications of the McCormick Observatory. The material consisted of the relative photographic proper motions measured in 340 regions fairly uniformly distributed north of — 30° declination. The average time interval between the plates was 12.6 years, the average limiting magnitude 12.4 Ipv. The average number of faint stars per region is 52.3, their average magnitude is 11.3 Ipv. Each region contains at least one bright star, reduced by the rotating sector to the tenth magnitude, whose absolute proper motion is given in the new General Catalog of the Dudley Observatory. The 340 regions contain a total of 574 GC stars or an average of 1.7 standard

stars per region, by means of which all proper motions were reduced to absolute. The system of proper motions is that of the PGC with Raymond's corrections applied to the proper motions in declination. This material is particularly valuable for the problem of mean secular parallaxes since a rigorous reduction to absolute motion was obtained for a large material of faint stars. A brief description of the analysis for mean secular parallax will now be given.

Precessional corrections were adopted, based on the mean of recent determinations of Oort,[28] and Plaskett and Pierce,[36, 37, 38] ($-\Delta e - \Delta l = -''.0110$, $\Delta p = +''.0104$), resulting in the following corrections to the proper motion components:

$$\begin{aligned} \Delta\mu_\alpha \cos\delta &= +''.0015 \cos\delta - .0041 \sin\alpha \tan\delta \\ \Delta\mu_\delta &= -''.0041 \cos\alpha \end{aligned} \tag{27}$$

The proper motion components were further corrected for differential galactic rotation the following constants[39] being adopted:

$$Q = -''.0029 \qquad P = +''.0033 \qquad l_0 = 327^\circ \tag{28}$$

Solar motion solutions for different galactic zones gave no appreciable change in the position of the apex, hence a combined solution was made for all zones together introducing a factor 1.4 for the coefficient of the solar motion terms in the zone $\pm 41^\circ$ to $\pm 90^\circ$ to allow for the larger value of $h\left(\overline{\frac{1}{r}}\right)$ in this zone. This solution gave the provisional coordinates of the apex: $A = 19^h.0$, $D + 35^\circ$ and a provisional dependence of $h\left(\overline{\frac{1}{r}}\right)$ on galactic latitude.

A general solution was now made for precessional corrections, differential galactic rotation and solar motion. This least-squares solution gave a probable error of $''.0061$ per region. Since the probable error of the reduction to absolute motion per region is only slightly less, namely, $''.0053$, the close agreement is an indication of the high cosmical accuracy of the mean proper motions.

The corrections adopted for the constants of precession and of differential galactic rotation were found to require no modification. Since a dependence of parallax on galactic latitude was introduced based on the adopted precessional corrections, the McCormick results for these corrections are not independent. However, an alternative

[36] Publ. Am. Astr. Soc. 8: 19. 1934.
[37] Month. Not. 94: 679. 1934.
[38] Publ. Dom. Astr. Obs. 5 (4): 1936.
[39] Lindblad, Stockholm Obs. Medd. No. 7, 1932; Scientia, May, 1932.

treatment by Oort[40] in which only the precessional corrections, the motion of the equinox and the constant B of galactic rotation are introduced as unknowns, gives practically identical results.

The final position for the apex in equatorial coordinates was found to be:

$$A = 19^h.0 \pm 0^h.2 \qquad D = +36° \pm 2°$$

which differs appreciably from the position of the apex derived from bright stars. It is of interest therefore that the high value of A is confirmed by supplementary solutions from the mean proper motions in right ascension of faint reference stars used in parallax determinations at the Allegheny, Yale and McCormick Observatories.

Before giving a detailed discussion of the McCormick mean secular parallaxes, it will be practical to give the results of a subsequent study of the effect on the elements of solar motion by a change from the system of the new General Catalog (GC) to the system of the "Dritter Fundamental Catalog" (FK3). This comparison has been made by Emma T. R. Williams and M. F. M. Osborne.[41] Instead of duplicating the earlier McCormick solution, which was made in galactic coordinates, Miss Williams used proper motions in right ascension and declination, assuming the same corrections for precession and galactic rotation as used in the detailed investigation. An excerpt of her solutions for solar motion is given in TABLE 1.

In comparing the results derived from the two systems the most striking feature is the shift in the position of the apex, mostly in declination, the average difference in the sense GC — FK3 amounting to 11°. Possibly the apparent progressive run of D with galactic latitude, particularly on the FK3 system is also worth mentioning.

A striking feature of the detailed McCormick investigation is that the mean secular parallaxes are on the average some 30 to 40 per cent higher in the northern galactic hemisphere than in the southern one. Miss Williams finds this to be true in both fundamental systems, but even more important, both the proper motions in right ascension and those in declination show the effect independently as may be seen for the separate data. The reality of this north-south effect seems, therefore, certain; another matter is whether it is of cosmical character or of spurious origin caused by differences in systematic errors in the northern and in the southern sky, common to both fundamental systems. On both systems the mean secular parallaxes have a minimum

[40] Bull. Astr. Inst, Netherlands 8: 149. 1937.
[41] Astr. Jour. 47: 43. 1938.

TABLE 1

SOLAR MOTION FROM McCORMICK STARS, ALL MAGNITUDES TOGETHER

(unit of $h\left(\frac{1}{r}\right)$ is ".001)

Fund. System	GC				FK3				
Galactic zone	A	D	$h\left(\frac{1}{r}\right)$		A	D	$h\left(\frac{1}{r}\right)$		No. of regions
+41° to +90°	271°	+41°	19.9±1.2		266°	+33°	19 5±1.1		70
+21° to +40°	277	+37	12.6	1.4	280	+24	13.9	1.5	42
+11° to +20°	285	+46	12.2	1.5	280	+31	12 0	1.7	31
0° to +10°	284	+25	16.0	1.5	284	+16	14 2	1.5	38
−10° to − 1°	285	+29	12.8	1.1	295	+17	10 4	1.1	42
−20° to −11°	294	+28	9.9	1.9	292	+15	8 0	2 2	23
−40° to −21°	285	+46	8.8	1 2	277	+34	6 9	1 2	45
−90° to −41°	296	+37	14.8	1 5	290	+29	15 0	1 5	49
±41° to ±90°	280	+39	17.3	.9	275	+31	17 2	.9	119
±21° to ±40°	281	+41	10.6	.9	275	+27	10 1	1.0	87
±11° to ±20°	289	+39	10.9	1.2	285	+25	9 9	1 3	54
0° to ±10°	285	+27	14 3	.9	284	+16	12 1	9	80

value around latitudes ± 20° although this effect is not appreciable in the FK3 system.

One more point is worth mentioning. On the GC system, in every case in which the component Y of the $h\left(\frac{1}{r}\right)$ is well determined by the declination equation, it is definitely smaller (in absolute value) than the Y determined by the right ascension equations. This inconsistency does not appear in the FK3 system.

A comparison of the GC and the FK3 values of $h\left(\frac{1}{r}\right)$ shows further that the differences are largest for low latitudes which may be partly explained by the position of the apex (galactic longitude 34°, galactic latitude + 14°).

When the McCormick material will have been appreciably extended, the choice of a fundamental system will be a most important matter. There can be no doubt that the result of the present detailed McCormick investigations are appreciably influenced by systematic errors of the GC system, although probably the general features of the results are fairly well established. For the present, Miss Williams'

investigation will be taken to indicate adequate stability of the behavior of the mean secular parallaxes in either the GC or the FK3 system. We shall therefore proceed to discuss in some detail the mean secular parallaxes as derived in McCormick Publication No. 7, which thus are based on the GC system.

The marked asymmetry between the northern and southern galactic hemispheres has already been mentioned; this effect appears to be accompanied by a similar asymmetry in the probable errors of one region. Undoubtedly this matter is one that deserves all possible attention. For the present, however, we have conservatively ignored the asymmetry in subsequent discussions; the combined results of the corresponding zones north and south of the galactic equator are given in TABLE 2.

TABLE 2

MEAN SECULAR PARALLAXES OF McCORMICK STARS

(unit ″.001)

Gal. zone \ Magnitude	8 7	10.0	11.0	11.9	12.7
±41° to ±90°	21.8±2.1	23.3±2.2	13.5±1.2	16.4±1.0	10.2±1.4
±21° to ±40°	21.8 2.3	12.8 1.4	14.2 1 2	8 0 .8	7.4 1.5
0° to ±20°	19.0 1.5	12.9 .9	11.3 .9	10.6 .8	9.1 1.1

On the average the decrease of parallax with diminishing latitude comes to a halt around latitude ± 20° with an increase toward the galactic equator strongly indicated. It is interesting to note that a similar effect was present in the material used by van Rhyn and Bok.[26] However, they could not very well arrive at any definite conclusion because of the discordant value of $h\left(\overline{\frac{1}{r}}\right)$ for the magnitude group 11.5 in the zone 20° to 40°.

The general behavior of the McCormick results is supported by those from the proper motions in right ascension of the Allegheny-Johannesburg and McCormick reference stars measured in parallax determinations (TABLE 3).

The influence of differences in systematic error between results derived from proper motions in right-ascension and in declination has been mentioned before. Since in the McCormick investigation all magnitude groups depend on the same sample of the fundamental systems, the similar dependence of $h\left(\overline{\frac{1}{r}}\right)$ on galactic latitude for the

TABLE 3

MEAN SECULAR PARALLAX OF ALLEGHENY-JOHANNESBURG AND McCORMICK REFERENCE STARS

(unit ″.001)

Gal. zone	All.-Joh. 10.9 pg	McC. 9 8 pv
±41° to ±90°	17.3± .9	20.5±2.5
±21° to ±40°	13.5 1.1	12.7±1.8
0° to ±20°	15.9 1 2	22.5±2.4

different magnitude groups may be partly of systematic observational origin. On the other hand, the change of $h\overline{\left(\frac{1}{r}\right)}$ with magnitude within a single galactic zone is independent of the fundamental stars. It is of a purely differential nature, and probably essentially free from magnitude error since a large number of regions contributed to each result. The slow decrease of $h\overline{\left(\frac{1}{r}\right)}$ with magnitude in the 0° to ± 20° zone, especially as compared with the ± 20° to ± 40° zone is more real than indicated by the probable errors given, since the cosmical errors due to the proper motions of the faint stars are small compared with those of the reduction to absolute motion.

Further information about the change of $h\overline{\left(\frac{1}{r}\right)}$ with magnitude for very faint stars has been obtained from a study of the relative photographic motions of 32,000 stars in the Radcliffe catalog[42] for selected areas 1–115. Assuming the apex to be RA = $19^h.0$, Decl. = + 36°, the relative mean secular parallaxes were found for seven groups between photographic magnitudes 9.0 and 15.9, referred to the mean secular parallax of stars of average magnitude 11 pg; these relative parallaxes were reduced to absolute by adding the mean secular parallaxes derived for the Allegheny-Johannesburg reference stars. Although these are based on proper motions in one coordinate only, and consequently have rather low weights in the zone 0° to ± 20°, a large number (1670) of Boss stars was used. This procedure makes the material practically independent of the McCormick material.

TABLE 4 gives the comparison of the different results for the mean secular parallaxes of faint stars with the extrapolated Groningen

[42] "The Radcliffe Catalog of Proper Motions." 1934.

values; for the Allegheny-Johannesburg and Radcliffe stars the tabulation was changed from photographic to photovisual magnitudes by applying a correction — $^m.5$ to the former.

The McCormick values of $h\left(\overline{\frac{1}{r}}\right)$ for the stars fainter than the tenth magnitude are larger than the computed values given by van Rhyn and Bok in Groningen Publications No. 45; for the 41° to 90° zone and for stars brighter than magnitude 10 there is fair agreement, however. There appears to be sufficient confirmation from the other data to permit the conclusion that the extrapolated values of the

TABLE 4
MEAN SECULAR PARALLAXES OF FAINT STARS
minus
GRONINGEN PUBLICATION No. 45 VALUES
(unit ″.001)

Material	McCormick					McC. All.-Joh. reference stars		Radcliffe			
Pv. Mag. / gal. zone	8.7	10.0	11.0	11.9	12.7	9.8	10.4	12.0	13.0	14 0	14.7
±41° to ±90°	−8.9	+1.6	−2.7	+4.2	+ .6	−2.4	−2.1	+1.3	+4.1	+2.3	+2.7
+21° to ±40°	+2.7	+ .9	+6.0	+2.3	+3.3	− .3	+3.0	+6.0	+3.9	+4.0	+3.8
0° to ±20°	−1.0	− .6	+1.5	+3.4	+3.5	+8.0	+3.8	+3.6	+6.5	+5.5	+5.1

Groningen mean parallaxes are not valid and should be corrected in accordance with the results derived here.

The present results for $h\left(\overline{\frac{1}{r}}\right)$ and the observational results of Groningen Publications No. 45 can be satisfactorily represented by a quadratic formula for each of the three galactic zones:

$$\log h\left(\overline{\frac{1}{r}}\right) = A + B\,(m - 8.0) + C\,(m - 8.0)^2 \qquad (29)$$

with the following values for A, B, C (TABLE 5).

TABLE 5

Galactic zone	A	B	C
±41° to ±90°	−1.472±0.011	−.1129±.0028	+.0043±.0010
+21° to ±40°	−1.615 .012	−.1298 .0031	+.0050 .0013
0° to ±20°	−1.620 .009	−.1099 .0023	+.0049 .0009

FIGURE 1 *a, b, c* (see also McCormick Publications, vol. 7, page 31) gives a graphic representation of the formula. In figure 1*d* these three curves are superimposed one upon another, and it is seen that at about the eighth magnitude the $h\left(\overline{\frac{1}{r}}\right)$ in the zone 0° to 20° is equal to that in the zone 21° to 40°. For fainter stars the minimum value

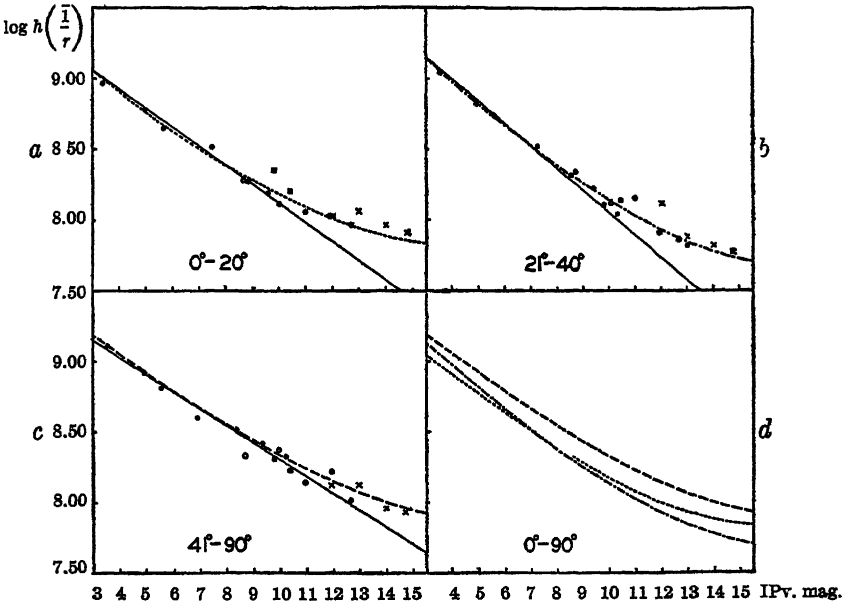

FIGURE 1. Mean secular parallax for different magnitudes in three zones of galactic latitude.
● Groningen Publ. 45; ■ All.-Joh. and McC. reference stars; ○ McCormick; × Radcliffe
-------- 0° to 20° —·—·— 21° to 40° — — — 41° to 90°
The curves represent the quadratic interpolation formula (29) (Table 5); the straight lines correspond to Table 7 of Gron. Publ. No. 45.

occurs in the zone 21° to 40° and beyond the 14th magnitude the $h\left(\overline{\frac{1}{r}}\right)$ in the zone 0° to 20° becomes almost as large as in the zone 41° to 90°.

By introducing simple functions of the galactic latitude b for the quantities A and B, the following double entry interpolation formula is obtained:

$$\log h\left(\overline{\frac{1}{r}}\right) = -1.53 - 0.10 \cos 2b - (0.06 + 0.04 \cos 2b + 0.09 \sin b)(m - 8.0) + 0.005\,(m - 8.0)^2. \quad (30)$$

The constants have been chosen in such a manner that a likely run of values with b results and in particular, that the mean parallaxes

for all magnitudes increase asymptotically to values at the galactic poles.

The cos $2b$ term in A was first introduced by Kapteyn, van Rhyn, and Weersma[23] and their value of the coefficient of this term, —.096, is very close to the present value. They assumed a constant value — .1373 for B; van Rhyn and Bok[26] derived the values — .120, — .158 and — .132 for the galactic zones 90° to 40°, 40° to 20° and 20° to 0 respectively while the present formula gives — .118, — .125 and — .114.

The computed values of $h\left(\overline{\frac{1}{r}}\right)$ from $m = 3$ to $m = 16$ are given in TABLE 6 (see also McCormick Publ. 7; table VI.2, page 70). It

TABLE 6

INTERPOLATED VALUES OF MEAN SECULAR PARALLAX (UNIT ONE SECOND)

Gal. Lat. / Vis. Mag	0°	±5°	±10°	±15°	±20°	±30°	±40°	±50°	±60°	±70°	±80°	±90°
3	0.099	0.108	0 118	0.125	0.134	0 148	0.160	0.167	0.172	0 175	0 175	0.176
4	.071	.076	.082	.086	.091	.100	.108	.114	.118	.121	.122	.123
5	.052	.055	.058	.061	.064	.069	.075	.079	.083	.086	.087	.088
6	.039	.040	.042	.044	.045	.049	.053	.056	.060	.062	.064	.065
7	.030	.030	.031	.032	.033	.035	.038	.041	.044	.046	.048	048
8	.0234	.0236	.0238	.0242	.0247	.0263	.0284	.0307	0331	.0352	.0366	.0372
9	.0188	.0186	.0185	.0186	.0189	.0200	.0215	.0234	.0255	.0274	.0287	.0292
10	.0155	.0154	.0147	.0151	.0148	.0155	.0167	.0183	.0201	.0218	.0230	.0234
11	.0130	.0125	.0121	.0119	.0118	.0123	.0133	.0147	.0163	.0179	.0189	.0193
12	.0112	.0106	.0100	.0098	.0097	.0100	.0108	.0120	.0134	.0148	.0158	.0162
13	.0099	.0092	.0085	.0083	.0081	.0083	.0090	.0100	.0114	.0126	.0136	.0140
14	.0089	.0081	.0074	.0072	.0069	.0070	.0076	.0086	.0098	.0110	.0120	.0123
15	.0082	.0074	.0067	.0063	.0061	.0062	.0067	.0076	.0087	.0099	.0108	.0111
16	.0078	.0069	.0061	.0057	.0055	.0055	.0059	.0068	.0079	.0090	.0099	.0102

should be noted that in these investigations no proper motions have been rejected on account of large values, and consequently the above interpolation formula will not represent the secular parallaxes of stars chosen on other bases.

CONVERSION FROM MEAN SECULAR PARALLAXES INTO MEAN DISTANCES

In order to convert the value $h\left(\overline{\frac{1}{r}}\right)$ for a certain group of stars into a mean value $\bar{r}$, it is necessary to know both h and the distribution of the individual r. The value of h is well-known from radial velocity determinations for the relatively bright stars but for stars

fainter than the tenth magnitude no determination of h has yet been made. A provisional study by the writer[43, 19, 32] has shown the feasibility of using small dispersion spectra for this problem. The radial velocities of 105 stars between visual magnitudes 9 and 10 and within 50° either of the apex or antapex were determined with a one-prism spectrograph and 6-inch camera attached to the 36-inch Lick refractor. The average probable error of a radial velocity derived from a good plate was found to be 14, 8 and 6 km/sec for stars of type A, F-G and K respectively. A solar velocity of 18 ± 2.2 km/sec ($3.8 \pm .5$ A.U./year) was found, believed to be affected by no systematic error larger than 1 km/sec, but this value is of provisional significance only. The errors of these radial velocities are less than the cosmical residual velocities and are therefore adequately small. An application to a large number of faint stars would be very desirable and would eliminate the necessity of hypothetical values of h that are now necessary to reduce values of $h\overline{\left(\frac{1}{r}\right)}$ to values of $\overline{\left(\frac{1}{r}\right)}$. The McCormick observers considered h to be a function of the spectral composition of the group of stars and used values ranging from $h = 3.8$ for the ninth magnitude stars in low latitudes to $h = 5.4$ for the thirteenth magnitude stars in high latitudes. In the present discussion we have preferred to adopt a constant value $h = 4.2$ A.U./year (or $V_0 = 20$ km/sec).

The reduction from $\overline{\left(\frac{1}{r}\right)}$ to $\bar{r}$ depends on the dispersion of r within the group. The assumption of a Gaussian distribution with dispersion in log r/r_0 appears convenient and leads to the simple relation

$$\bar{r} \cdot \overline{\left(\frac{1}{r}\right)} = e^{\sigma^2_r/\mathrm{mod}^2} \tag{31}$$

where for the same apparent magnitude $\sigma_r = 0.2$ times σ_M, the dispersion in a Gaussian distribution of the absolute magnitudes.

It is difficult to obtain information of σ_r (or σ_M) independent of any hypothesis. A knowledge of spectra leads to a range[22] in σ_M of 0.7 for type A to 2.4 for type G5. For stars of all types together $\sigma_M = 2.0$ or $\sigma_r = 0.4$ may be taken as a maximum value; this would lead to the following conversion:

$$\bar{r} \cdot \overline{\left(\frac{1}{r}\right)} = 2.34 \tag{32}$$

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[43] Lick Obs. Bull. 12: 88. 1926.

As an illustration of the penetrating power of the secular parallax method we have made use of the above given assumptions for h and σ_r, and thence derived values for $\bar{r}$ from the McCormick values for $h\left(\overline{\frac{1}{r}}\right)$ given in TABLE 2 by means of the relation

$$\bar{r} \cdot h\left(\overline{\frac{1}{r}}\right) = 9\ 8 \tag{33}$$

The results are given in TABLE 7.

TABLE 7

MEAN DISTANCE OF MCCORMICK STARS

(unit 1 parsec)

Gal. zone \ Magnitude	8.7	10 0	11 0	11 9	12 7
±41° to ±90°	450	420	730	600	960
±21° to ±40°	450	770	690	1200	1320
0° to ±20°	520	760	870	920	1080

A similar TABLE 8 has been derived from the interpolated mean secular parallaxes of TABLE 6:

TABLE 8

PROVISIONAL MEAN DISTANCES OF FAINT STARS BASED ON TABLE 6

(unit 1 parsec)

Gal. lat. \ Magnitude	10	11	12	13	14	15	16
±90°	420	510	600	700	800	880	960
±60°	490	600	730	860	1000	1130	1240
±40°	590	740	910	1090	1290	1460	1660
±20°	660	830	1010	1210	1420	1610	1780
0°	630	750	870	990	1100	1190	1260

It is clear that the absolute values of the quantities in TABLES 7 and 8 are uncertain, but their dependence on magnitude and latitude is probably approximately correct. At this point it is important to remember that the annual parallax method is of no practical value beyond 100 parsecs. The secular parallax method takes us about ten times as far. It appears that at this distance the increase of average distance with fainter magnitude is small in high galactic

latitudes ($\pm 60°$ and over) and near the galactic equator; but at intermediate latitudes (about $\pm 20°$) the increase continues to hold. The McCormick observers have shown that these features can be explained by assuming a density function which depends on the perpendicular distance z from the galactic plane only, a constant luminosity function and a galactic absorbing layer of constant lateral optical thickness. A photovisual absorption constant of somewhere between 2 and 4 magnitudes per kilo-parsec is required to explain the slow decrease in parallax in low latitudes. Because of the large dispersion in absolute magnitudes the mean parallaxes for all spectra combined are not any too sensitive a criterion for an accurate determination of the absorption constant. This is especially conspicuous for the fainter group, in which already a relatively small absorption screens off a high percentage of the stars of small parallax and of which a considerable number of stars is outside the absorbing layer. Hence, it appears that stars brighter than about the 11th or 12th magnitude are most important for determining the absorption coefficient.

So far we have considered stars without regard to spectral type. The zone catalogs have given much information about the proper motions of stars of different spectral types down to visual magnitude 8. The McCormick observers included a spectral group of average magnitude 10; it is noteworthy that at this magnitude the mean secular parallaxes of the A and K stars are about as small as the corresponding values for all stars together at magnitude 12.7. Because of the added spectral information such groups furnish an expedient means for a study of galactic structure especially if it would be shown that the general structural features are well represented by stars of selected spectral types.

CURRENT INVESTIGATIONS; DESIDERATA

The most serious obstacles to increasing our knowledge of mean secular parallaxes are the limitations in accuracy due to precession and systematic errors in the proper motions of the standard stars. Eventually the natural solution can be found from a photographic survey of the sky with large angle cameras of adequate aperture and focal length, repeated after a sufficient interval. The extragalactic objects on these plates would serve as an external reference system.

In the meanwhile improvements may be expected from the aforementioned transfer to fainter stars through the repetitions of the Astronomische Gesellschaft zones by Schlesinger's large angle cameras.

Because of the success of this method, an extension toward fainter magnitudes might well be considered.

A limited systematic transfer to much fainter stars is to be found in Kapteyn's plan of Selected Areas. Large scale photographs have been used for these, insuring high accuracy of the relative motions, as, for instance, shown by the Radcliffe Motions in the Selected Areas 1 to 115. At the same time, the absolute proper motions of the brighter stars in the Selected Areas are being determined; the first results have been published by Hins[44] for the same Areas 1 to 115. The weak point here lies for the time being in the limited number of reduction stars and possible magnitude error. An excellent scheme has been started, however, by Schlesinger[45] in 1934 to solve effectively the problem of absolute motions in the Selected Areas. Overlapping plates are taken in Johannesburg with a long focus telescope which has a grating in front of the lens giving a difference of about five magnitudes between central and first order images. Plates centered on the same regions are also taken with a Ross Camera using plates covering 110 square degrees. A grating with a magnitude interval of 3.5 is placed in front of the Ross lens. The camera plates will be reduced by means of all GC stars (on the average nearly 100) that appear on them. These plates give stars fainter than 12 pg, the plates taken with the large telescope stars fainter than 15 pg. In this manner a considerable transfer from observational to cosmical accuracy will be obtained.

An important improvement is at present being made at the McCormick Observatory where the transfer from standard stars to surrounding faint stars is being continued. It should be realized that with this method advantage is taken in a very effective way of the accurate motions of the standard stars, their homogeneous distribution over the sky and the accurate long focus transfer to cosmically accurate objects. Because of favorable climatic conditions the McCormick Observatory is in a position to carry out this investigation down to — 40° declination. Attention should be drawn to the potential material at the Allegheny Observatory and especially at the Yale Southern Station which could provide uniform coverage of the sky.

The significance of these transfers is well illustrated by describing the possible improvements in the *precessional corrections*. The precessional values as derived from the absolute motions of the Albany

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[44] Ann. Sterrewacht Leiden, 15: pt. 3. 1930.
[45] Trans. Int. Astr. Union 5: 207. 1936.

General Catalog have probable errors of $''.0006$ and this small error has been obtained partly because of the exclusion of stars having a proper motion larger than $0''.8$. It is obvious that this error is larger than would be desirable in many proper motion investigations; it means that in opposite areas of the sky a systematic difference of several times $''.001$ may exist because of uncertainties in precessional values. It is, therefore, important to consider what improvements can be made in the future. With a uniform distribution over the sky of N objects whose annual variations have been observed, the weights of the corrections Δm and Δn are $\frac{N}{2}$, whence weights of $\frac{N}{2}\sin^2\epsilon = .08N$ for Δp and Δl. Now, as far as the precessional problem is concerned, the error of the annual variation of one object is made up of the terrestrial error of observation and the cosmical error, the latter is the residual motion remaining after allowance is made for systematic motions which are expressed in analytical form, rigorous in case of precession, approximate for galactic rotation and parallactic motion.

Let the probable observational error be R_0 and the probable cosmical error R_c hence the total probable error $R = \sqrt{R_0^2 + R_c^2}$. The effective weight of an object for the precessional problem is therefore proportional to $\frac{1}{R_0^2 + R_c^2}$.

Adopting $''.001$ as the probable error of unit weight, a summary computation[46] shows that the total observational weight of the new General Catalog is 1258, or about 45 times the cosmical weight (28) which in this case is practically the effective weight. Thus, precessional corrections based on the motions of the GC stars have a weight of only $.08 \times 26 = 2.24$, or a probable error of $''.00067$.[47]

For a precessional solution based on GC stars then, the high accidental accuracy of the proper motions is of minor significance because of the cosmical inaccuracy. Nor will a future reduction in the accidental errors of the GC proper motions lead to the slightest increase in the accidental accuracy of the precessional constants; the latter is limited by the cosmical weight (2.24) of this catalog.

However, complete transfer to cosmically highly accurate, *i. e.*,

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[46] Astr. Jour. **48**: 21. 1939.

[47] This is only slightly larger than the values $''.00062$ and $''.00063$ obtained by Wilson and Raymond (Astr. Jour. **47**: 57. 1938) from a discussion of the proper motions of the new General Catalogue. The difference with the predicted value is irrelevant and may easily be explained by the uncertainties in our adopted R_c, and also by the exclusion of large proper motions by Wilson and Raymond.

practically fixed objects, would yield precessional corrections with a weight $.08 \times 1258 = 101$; *i. e.*, a probable error of $''.0001$. A greater potential accuracy even will become available in the future through additional observations on the (fainter) GC stars. For example, a uniform probable error of $''.002$ would yield a total terrestrial weight of $.08 \times 8325 = 666$. Complete transfer to a cosmically fixed system would then result in probable errors of only $''.00004$, or 6% of the present probable error, for the precessional constants.

It should be clearly understood however, that the above summary computation refers to internal accuracy based on an accidental behaviour of both observational and cosmical errors. In any case, *systematic errors* would make the results decidedly unfavorable. It is imperative that improvement of the systematic accuracy of the proper motions of standard stars be obtained, and that the systematic differences between fundamental systems like the GC and the FK3 are clarified. Until such has been done a transfer to much fainter stars than has been done by the McCormick observers, seems hardly warranted.

Some information about systematic errors could, of course, be obtained from a program of extensive radial velocity observations of faint, say 10th magnitude, stars. Such an investigation would also provide much useful knowledge about the sun's velocity with respect to these stars, a quantity needed for the conversion of mean secular into mean annual parallaxes, and about the residual motions for these stars.

A few remarks will now be made on the relation between the extragalactic and the intergalactic reference system.

The advantage of the *extragalactic reference system* as provided by the extragalactic objects lies in the negligible proper motions. According to Hubble the mean absolute magnitude for nebulae of a given apparent magnitude is -15. We thus find the following distance modulus (ignoring opacity):

$$5 \log r - 5 = m + 15$$

or

$$\log r = 0.2\, m + 4 \tag{34}$$

If we assume[48] a maximum residual radial velocity (after correction for group motion and average recession) of 500 km/sec or about 100 A.U./year, then the residual proper motions in one coordinate for objects of apparent magnitude 15 and fainter are less than $''.00001$!

[48] Oort, Bull. Astr. Inst. Netherlands 5: 158. 1931.

However, the extragalactic reference system has its limitations in the following:

1. The areal extent of the extragalactic objects.
2. The deficiency of these objects in low galactic latitudes.
3. The impossibility of observing by meridian circle so that positions in the extragalactic reference system can be obtained only by overlapping photographs covering the whole sky.

According to Hubble[49] the major diameter of the bright nuclear region of the Andromeda nebula is 3,000 light years or thus about 1,000 parsecs. We shall adopt 1,000 parsecs as the effective diameter which determines the photographically measurable nucleus of an extragalactic object and thus find for the apparent effective diameter in seconds of arc

$$\log d'' = 4.3 - 0.2\ m. \tag{35}$$

TABLE 9 illustrates formulae (34) and (35).

Not until about the twentieth magnitude do the extragalactic objects become star-like, but for brighter magnitudes sufficient symmetry may exist or an artificial magnitude reduction may be provided by gratings so that measurable images result.

The deficiency in low latitudes will be studied for the simplified case of a uniform distribution in space and a galactic absorbing layer of uniform optical thickness. We adopt Hubble's data and thus have

$$\log N_{m,\,b} = 0.6\ m - 9.1 - 0.15 \operatorname{cosec} b \tag{36}$$

where $N_{m,\,b}$ is the number of extragalactic objects per square degree, m the apparent photographic magnitude and b the galactic latitude; the correction for redshift has been ignored.

The general features of the distribution of extragalactic objects are well expressed by this formula. The lack of objects in low latitudes appears to be a serious matter, in view of the particular structural importance of the regions in low galactic latitude. It may very well be that penetration to fainter magnitudes will bring out an adequate number of objects; photography in the red would probably do so. It may also be possible with plates covering sufficiently large areas to bridge the spaces which are completely lacking in extragalactic objects. In case none of these attempts would be successful, we would have to compromise by introducing an auxiliary intergalactic reference system conveniently provided by stars, since the decrease in frequency of the nebulae toward lower latitudes is compensated by

[49] "The Realm of the Nebulae." 135. 1936.

an increase in the available number of potential standard stars. This is illustrated in the TABLE 10. The star numbers refer also to photographic magnitudes and have been derived from van Rhyn's star counts,[50] averaging north and south. The complimentary behavior of the distribution of the two classes of reference objects is clearly shown.

For the purpose of obtaining a closed extragalactic reference system of absolute α and δ over the whole sky, we will again have the problem of absolute meridian circle *positions* with the full difficulties of systematic error caused by refraction and seasonal errors. However, for the limited problem of annual variations the difficulties would practically be non-existent, since we are only concerned with relative measures. In this case the precessional corrections would be eliminated by using the extragalactic reference system and even large angle photographs would give fully adequate proper motions which are not primarily dependent on accurate scale, refraction and other constants. The question, however, is whether the annual variations of the possible auxiliary standard stars can be kept free from *changes* in systematic errors.

In connection herewith, we should consider the important matter of choice of photographic range of wavelength. There are numerous advantages in astronomical photography in longer wavelengths. Greater photometric penetrating power is provided, both cosmically and through the earth's atmosphere. Apart from this there is a considerable reduction in atmospheric dispersion toward longer wavelengths, as shown by the dispersion formula of Kayser and Runge[51]

$$\sin R = 0.0002879 + .00000132/\lambda^2 + .000000032/\lambda^4 \qquad (37a)$$

$$\text{or: } dR/100 \text{ Å.U.} = -.0528/\lambda^3 - .00256/\lambda^5 \qquad (37b)$$

(R = refraction constant, λ is expressed in microns).

The tremendous increase of the atmospheric dispersion toward shorter wavelengths demonstrates the advantage of positional work in wavelengths longer than the conventional photographic range (TABLE 11). This has been gradually realized in parallax and other long focus astrometric problems. The photographic effective wavelength is usually between λ 4000 and λ 4500, and is strongly dependent on spectral type. In photovisual photography the effective wavelength is about λ 5500. Here the dispersion is several times smaller, and by using a yellow filter the range in effective length for different

[50] Groningen Publ. No. 43, table 6, 75. 1929.
[51] Astr. Nachr. 192: 315. 1912.

spectral types becomes negligible. With a photovisual combination at λ 5500 both Hertzsprung[52] and Strand,[53] for example, find an increase of effective wavelength of about 20 Å. from spectral types A to K, which corresponds to a decrease in the refraction constant of ″.007 only. In conventional photographic astrometry at about λ 4500, a change of 200 Å. may exist for the same change in spectral type, giving a difference in the refraction constant of over ″.1!

The erstwhile objections of the relative speed of yellow sensitive and blue sensitive emulsions do not appear to hold any more since the increase in speed in the photovisual range has been between 15- and 20-fold during the past twenty-five years.

TABLE 9

m	Distance in megaparsecs.	Apparent effective diameter
14	6 3	32″
15	10	20
16	16	13
17	25	8
18	40	5
19	63	3.2
20	100	2.0
21	160	1.3

TABLE 10

NUMBER OF OBJECTS PER SQUARE DEGREE DOWN TO DIFFERENT MAGNITUDES

	Stars						Extragalactic objects						
pg. mag. / gal. lat.	5	6	7	8	9	10	14	15	16	17	18	19	20
0°–5°	.055	.15	.42	1.1	3 3	12	—	—	—	.004	.018	.07	.28
5 –10	.042	.12	.32	1 0	2.5	7	.01	.06	.23	.9	3 6	14	60
10 –20	.031	.09	.25	.69	1.9	5.2	.05	.21	.83	3.3	13	50	210
20 –30	.023	.066	.19	.53	1.4	4 0	.09	.35	1.4	6	22	90	350
30 –40	.019	.056	.16	.44	1.2	3.2	.11	.4	1.7	7	28	110	440
40 –50	.017	.050	.14	.39	1.0^{5}	2.8	.12	.5	2.0	8	31	120	490
50 –60	.015	.046	.13	.35	1.0	2.4	.13	.5	2.1	8	33	130	520
60 –70	.014	.044	.12	.33	1.0	2.2	.13	.5	2.1	9	34	135	540
70 –80	.013	.042	$.11^{5}$	.31	1.0	2.0	.14	.5	2.2	9	35	140	550
80 –90	.013	.041	$.11^{2}$	30	1.0	2.0	.14	.6	2 2	9	35	140	560

[52] Publ. Aph. Obs. Potsdam No. 75, 13. 1920.
[53] Ann. Sterrewacht Leiden 18: pt. 2, 7. 1937.

TABLE 11

REFRACTION AND DISPERSION CONSTANT

λ	R''	Dispersion per 100 Å
4000Å	61''.34	−1''.08
4500	60 .89	− .72
5000	.58	− .50
5500	.33	− .37
6000	.19	− .28
6500	60 .06	− .21
7000	59 .96	− .17
7500	.89	− .14
8000	.83	− .11
8500	.77	− .09
9000	.73	− .08
9500	.69	− .07
10000	59 66	− .06

MEAN PARALLAXES FROM PECULIAR MOTIONS

By Emma T. R. Williams

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The publication in recent years of several catalogs of proper motions of stars fainter than tenth magnitude, has made possible a number of investigations into the mean parallaxes of these stars. Most of these discussions deal with peculiar motions, because, with two exceptions, relative rather than absolute motions have been published in the catalogs and these are better suited to investigations of peculiar rather than of parallactic motions. It is desirable that both types of investigation should be made because of the value of various independent approaches. Here, however, we shall consider chiefly the mean parallaxes from peculiar motions.

MATERIAL

There are six chief sources of photographic proper motions of stars fainter than 10th magnitude, if we exclude investigations in which only stars of large motion are measured. These are listed in TABLE 1 in order of publication.

TABLE 1

Observatory	No. of Areas	No. of Stars	Average Limiting Pg. Mag.	Average p. e. Rel. Motions	Portion of Sky Sampled
Groningen[1]	33	4,665	12.0:	0″.006	....
Cambridge[2]	31	3,247	12.3:	.004	0° to +60°
Radcliffe[3]	115	32,400	15.2	.004	0° to +90°
McCormick[4]	341	17,782	13.3:	.006	−25° to +80°
Pulkova[5]	74	17,997	14.8:	.0046	+15° to +75°
Cape[6]	1512	41,397	11.2:	.005	−40° to −52°

[1] Publ. Kapteyn Astr. Lab. Groningen, Nos. 28, 30, 33, and 39, 1918–25. Twenty-four of the regions lie in the Zone −40° to −50°; the other nine are scattered in the northern sky.

[2] Cambridge Astr. Obs. 24. 1928. Twenty-five of the regions lie within 20° of the galactic circle.

[3] The Radcliffe Catalogue of Proper Motions. 1934. These are Kapteyn Selected Areas.

[4] AJ 46: 9. 1937; or Publ. Leander McCormick Obs. 7. 1937.

[5] Publ. Pulkova Obs. 55. 1940. These are Kapteyn Selected Areas.

[6] Proper Motions of Stars in the Zone Catalogue of 20,843 stars, 1900, Royal Observatory, Cape of Good Hope, 1936. This volume includes chiefly stars brighter than 10th magnitude. The volume containing the motions of 20,554 fainter stars has not yet been received although it was reported as ready for the press three years ago in MN 98: 491. 1938. The error, 0″.005, seems to apply to stars brighter than tenth magnitude.

The Cambridge motions have been analyzed by Smart and by Stenquist; however, I have not included Smart's investigation[7] in this discussion since he deals in the main with stars brighter than tenth magnitude. The Radcliffe motions have been discussed by Oort and by van Hoof, and the McCormick motions by the McCormick observers. The other catalogs have not as yet been used for the derivation of mean parallaxes from peculiar motions. In the case of the McCormick and Pulkova motions, reduction to absolute motion was effected by means of bright stars of known proper motions. In the other cases the reduction was indirect, by means of extrapolations from the Groningen tables of secular parallaxes, etc.

METHODS

It is fortunate that the methods employed by the various investigators are diverse and that three different catalogs of motions have been used. The simple text-book formula for deriving the mean parallaxes from tau-components is:

$$\bar{p} = \frac{4.74\,\overline{|\tau|}}{\overline{V}}$$

where $\bar{p}$ is the mean parallax, $\overline{V}$ is the mean peculiar velocity in kilometers per second obtained from stars of known radial velocity, or known parallax and proper motion, and $\overline{|\tau|}$ is the arithmetical mean of the tau-components disregarding sign. Here, $\overline{|\tau|}$ must be corrected for the systematic influence of the accidental errors. We have, approximately,

$$\overline{|\tau|}^2_{\text{corrected}} = \overline{|\tau|}^2_{\text{observed}} - (\text{average error})^2$$

Obviously it is desirable that the average error be relatively small if we are to place much confidence in $\overline{|\tau|}_{\text{corrected}}$.

However, none of the four investigations published in the past five years has used this simple formula as it stands, because by this time we have sufficient knowledge of the velocity distribution of the stars to be able to take into account the fact that the mean peculiar velocity is not the same in all directions. In fact, only two of the four investigations deal with tau-components, namely, that of van Hoof[8] which was undertaken at the suggestion of Professor Oort, and that of the McCormick observers[4] for which the present author was responsible. Van Hoof assumed the relative lengths of the axes of

[7] MN 96: 132. 1935.
[8] BAN 8: 67. 1936

the velocity ellipsoid as 1.00, 0.63, and 0.50, whereas McCormick assumed them as 1.00, 0.75, and 0.50. In both investigations, allowance was made for the variation of the size of the velocity ellipsoid with spectral type and luminosity, but no account was taken in either of the variation of the shape of the ellipsoid.[9] To find the mean value of the peculiar velocity in the direction of the tau-component of any particular region, the same formula was used in both investigations. The chief differences in procedure between the two investigations follow: (*a*) van Hoof used tau-components referred to the algebraic mean of all the tau-components of stars of the same magnitude class in the region, whereas McCormick used the tau-components of motions which had been reduced to absolute motions by means of the known absolute motions of bright stars in the region and also by the mean parallactic motion of all the stars in the region; (*b*) for each class in each region van Hoof corrected $\overline{|\tau|}_{\text{observed}}$ by means of the relative accidental errors and immediately derived the corresponding value of $\bar{p}$, whereas McCormick first grouped a number of regions together, then corrected by means of the absolute accidental errors and finally derived $\bar{p}$ for the group; and (*c*) van Hoof presumably spread the effect of the large proper motion stars in some manner similar to the one mentioned in the next paragraph whereas McCormick excluded three stars (out of 18,000) with proper motion larger than 0″.5.

A variation of the tau-component method was used by Oort.[10] His investigation was based on the same catalog of proper motions as that of van Hoof and is similar in nearly every respect except that instead of using tau-components he used a new component which he designated as μ_t. For each region he chose the direction of μ_t so that it would lie as nearly as possible parallel to the principal axis of the velocity ellipsoid without coming within 66° of the direction to the solar apex. By doing this, he increased the size of the component relative to the size of the accidental error, an advantage particularly with respect to the faintest groups of stars. But this procedure necessitated corrections to the motions to eliminate the effect of the component of the parallactic motion which was thus unavoidably introduced. Again, in order to avoid the irregularities caused by stars of large proper motion (greater than 0″.1 in the μ_t direction) he treated these stars separately, spreading their effect over all the regions.

[9] Thus Nordstrom finds evidence that the ellipsoid is more elongated for the main sequence stars than for the late type giants. Medd. Lund. 2 (79): 1936.
[10] BAN 8: 75. 1936.

A fourth investigation of mean parallaxes from peculiar motions was made by Stenquist.[11] His procedure is a modification of the method of the Charlier school. For each star in his investigation he determined the absolute magnitude by Lindblad's spectrophotometric criteria. Then he grouped the stars according to the spectral class and the modulus (m-M) and solved the material of each group for the velocity ellipsoid, making suitable allowance for the influence of errors in the apparent and absolute magnitudes and also for the errors in the motions. Since the axes of the ellipsoids derived from stars of large modulus are in every case much larger than those derived from stars of the same spectral type but smaller modulus, and these in turn are larger than those of nearby stars, he was able to draw conclusions as to the amount of absorption of light in space and the corresponding distances of the various groups. He used relative motions for his velocity ellipsoid solutions, referring both components of motion (namely τ_l and τ_b) to the mean of the motions of all stars in the same group and area.

MEAN PARALLAXES OF STARS GROUPED ACCORDING TO MAGNITUDE

There are several assumptions underlying the derivation of mean parallaxes of magnitude groups, since it is necessary to estimate the relative numbers of giants and dwarfs and the lengths of the axes of the velocity ellipsoid for dwarfs. It is to some extent fortuitous that the size of the resulting composite ellipsoid as estimated by the Leiden investigators is in such close agreement with that estimated independently by the McCormick investigators for the twelfth and thirteenth magnitude groups in the different zones of latitude and it does not necessarily indicate that they are both nearly correct. In TABLE 2 is presented a comparison of the mean parallaxes for these two magnitude groups.[12] The fourth set has been obtained from the McCormick parallactic motions on the assumption of a solar velocity of 20 km/sec for each group. There is no justification for this assumption except that when it is used the mean parallaxes from the McCormick parallactic motions agree on the whole better with those from the McCormick peculiar motions than when higher solar velocities are assumed in higher latitudes. Actually we have very little observational knowledge as to the solar velocity with respect to stars at such great distances from the galactic plane. Since we

[11] Upsala Medd. No. 72. 1937.

[12] Stenquist made no investigation according to magnitude groupings.

TABLE 2

Investigation	Mean Galactic Latitude	No of Areas	No. of Square Degrees	Mean Pg. Mag. 12.0 No. of Stars	Mean Pg. Mag. 12.0 $\bar{p}$	Mean Pg. Mag. 13 0 No. of Stars	Mean Pg. Mag. 13 0 $\bar{p}$
van Hoof	8°	17	8	300	″.0019	700	″.0015
van Hoof	26	19	13	300	.0022	600	.0021
van Hoof	53	18	18	200	.0033	400	.0025
Oort	4°	14	6	312	.0018 ± 00014	754	0014 ±.00010
Oort	12	14	6	193	.0021 ± 00018	537	.0015 ±.00012
Oort	25	17	12	275	.0027 ± 00011	664	0021 ±.00007
Oort	62	21	21	198	.0043 ± 00022	456	.0028 ±.00007
McC ($\overline{\lvert\tau\rvert}$)	5°	81	45	2600	.0026 ± 00013		
McC ($\overline{\lvert\tau\rvert}$)	15	54	30	1100	.0024 ± 00013		
McC ($\overline{\lvert\tau\rvert}$)	30	86	48	900	.0028 ± 00012		
McC ($\overline{\lvert\tau\rvert}$)	57	119	66	750	0034 ± 00009		
McC (h/r)	5°	81	45	2600	0028 ± 00018	2500	0026 ± 00020
McC (h/r)	15	54	30	1100	0023 ± 00024	1100	.0019 ± 00027
McC (h/r)	30	86	48	900	.0026 ±.00017	800	0018 ± 00020
McC (h/r)	57	119	66	750	0035 ± 00019	700	0031 ±.00020

have assumed an increase in the peculiar motions with latitude, it appears to controvert the Stromberg diagram to assume a constant solar velocity, but perhaps this is justifiable.[13] The probable errors in TABLE 2 were derived in every case from the interagreement of the data. Van Hoof's probable errors are presumably of about the same size as those of Oort. Oort's errors are relatively small because of the fact that he smoothed the effects of the large proper motion stars. The mean parallaxes from the McCormick tau-components are regarded as too unreliable at the thirteenth magnitude to justify their inclusion.

Van Hoof has already shown that there is very good agreement between his mean parallaxes and those of Oort when the same selected areas are considered. Actually, van Hoof discussed a somewhat different set of areas from those used by Oort and consequently their mean parallaxes differ considerably in high latitudes, but no more than would be consistent with their probable errors. It is to be expected that these two sets of results would agree with one another since they are based on the same catalog of motions and reduced with the same underlying assumptions. In fact, they cannot be regarded as independent determinations of mean parallaxes.

Comparing the four sets of values of mean parallaxes in TABLE 2, we find the agreement entirely satisfactory except in the lowest latitudes. Here we find the same sort of disagreement which will be

[13] *Cf.* **Williams, ApJ 84: 346. 1936; Oort, BAN 8: 84. 1936; Bruna, MN 99: 248 1939.**

shown in TABLE 6 for the low latitude A stars. Both the Leiden-Radcliffe discussions show considerably smaller parallaxes than the two McCormick discussions and the Stenquist discussion. The fact that the agreement in higher latitude zones is satisfactory points to the conclusion that it is not the method of treatment but the selection of the regions in low latitudes which introduces the discrepancy. Oort has only fourteen regions in galactic latitudes less than 10° and van Hoof has only eight, so that there is considerable danger of sampling error arising from irregularities due to absorption and undetected moving clusters. In particular, neither investigation included any region within 40° of the direction toward the galactic center. It is true that the Kapteyn areas discussed by Oort were originally chosen with a view to avoiding extremes of apparent absorption and clustering, but it may be questioned whether such a selection would give us the same results as a large number of areas selected at random. For the large parallaxes in a heavily obscured area will probably more than counterbalance the small parallaxes in an area free from absorption so that the mean parallax from the two areas would tend to be larger than the mean parallax from Kapteyn's "average" or "normal" regions.[14]

For the magnitude groups 10.0 and 11.0 the agreement is not so satisfactory. Oort's values being about 25 per cent greater than the McCormick values except in the lowest latitudes, where they agree. This is doubtless due to the fact that Oort treated these brighter stars in a somewhat different manner since they were few in number. Probably the McCormick values are more reliable here.

For the magnitude groups fainter than thirteen where no spectra are available the situation is not so favorable since the peculiar motions are functions of spectral class and since the spectral distribution is essentially irregular. It was Pannekoek, I believe, who was the first to point out this unevenness.[15] From a study of the A and K stars of the Henry Draper Catalog he concluded that "the condensations of the K stars generally do not correspond to those of the A stars." Such irregularities in spectral distribution may be verified from an inspection of the McCormick spectral plates. To illustrate this point we may examine the spectral statistics in the Selected Areas with galactic latitude less than 10° which have thus far been published at Bergedorf. There are just ten of these regions. If we find a pair of areas in the same galactic latitude and with approximately the

[14] Kapteyn, "Plan of Selected Areas," pp. 7, 15, and 16, 1923.
[15] Publ. Astr. Inst. Univ. Amsterdam No. 2. 67. 1929.

same number of A stars, we might assume that the number of K and M stars would also be about the same. But this is not at all the case as is shown by the three comparisons in TABLE 3. Here the

TABLE 3

Sel. Area (1)	Galactic Long. (2)	Galactic Lat. (3)	Star Counts from Bergedorf Spectral Statistics: B6–B9 10.5–11.5 m (4)	A0–A4 11.0–12.0 m (5)	K0–K4 12.0–13.0 m (6)	K5–M 12.0–13.0 m (7)	B6–A4 0–8.5 m (8)	Oort's $\bar{p}$ All Spectral Types 11.5–12.4 m (9)	Oort's $\bar{p}$ All Spectral Types 12.5–13.4 m (10)
25	133°	+9°	16	42	40	8	14	″ 0016	″.0017
39	47	+9	13	55	133	69	12	0021	.0023
	Ratio		*1.2*	*0.8*	*0 3*	*0.1*	*1.2*		
18	68	+6	32	92	42	4	13	0031	0017
23	120	−7	27	75	53	26	18	.0000	.0027
	Ratio		*1.2*	*1 2*	*0.8*	*0.2*	*0.7*		
9	106	+3	37	88	31	5	23	0011	0012
40*	53	0	41	113	59	45	28	not used	
	Ratio		*0 9*	*0 8*	*0 5*	*0 1*	*0.8*		

* At the conference Professor Bok criticized the inclusion of SA 40 in the comparison, on the ground that the obvious irregularities make it unrepresentative. It appears that in the heavily obscured parts of the area the number of KO-M stars is about the same as the number of B6-A4 stars, whereas in the star clouds the ratio is about half as great. However, even excluding the obscured parts of this area, the tendency shown in TABLE 3 would still be well pronounced.

magnitude limits in columns 4 to 7 are so chosen that in each area stars in approximately the same region of space are counted. In each of the six areas, stars fainter than $13^m.5$ are classified so that the counts quoted in TABLE 3 are probably about complete. It is seen that the relative excess of late type stars in areas 39, 23, and 40 becomes most marked in the latest types. If the excess were largely due to dwarfs in nearby star clouds we should expect an excess of A stars in the brightest group (column 8); and we should expect much larger mean parallaxes than those found by Oort (columns 9 and 10). A possible alternative is that the galactic star clouds are characterized in some degree by the same type of spectral inhomogeneity as is found in the galactic clusters. In any event, it appears that such wide variations in relative spectral distribution are not unusual. Probably there is no more justification for regarding the luminosity function as a constant function of the latitude than there is in the case of interstellar absorption, but both assumptions must be made in the absence of more detailed knowledge.

Van Hoof's faintest magnitude group is at $14^m.5$ and Oort's at $14^m.8$. When use is made of the low latitude material, the disagreement in mean parallaxes in the brighter groups should be borne in mind.

Oort states that his mean parallaxes for these stars are not so trustworthy on account of uncertainties as to the errors. Now that the Pulkova motions for the Selected Areas are available, the errors may be considerably reduced for the faint stars by a combination of the two sets of measures. Although the limiting magnitude of the Pulkova material is about half a magnitude brighter than that of the Radcliffe material in the average, there is still sufficient material to improve considerably on the reliability of Oort's faintest group.[16]

It appears to be too early to present a table of the most probable mean parallaxes in view of the outstanding discordance in the lowest latitudes. More light will be thrown on this question in a couple of years when the second instalment of the McCormick general proper motion program is completed. Furthermore, the reference stars from the McCormick program for Cepheid proper motions will include more than 500 A stars and the accuracy of their motions will be comparable with those of Smart, Radcliffe, and Pulkova.

It should be mentioned that if there is any considerable tendency for the stars to move in open cluster formation then all of the mean parallaxes in low latitude will be systematically too small, since they are all derived from relative motions rather than absolute.[17]

NORTH-SOUTH ASYMMETRY

There is another aspect of the matter to be considered. The McCormick discussion of tau-components indicates that the mean parallaxes north of latitude $+20°$ are, zone for zone, systematically about ten per cent greater than those south of $-20°$. The McCormick secular parallaxes show a much more pronounced effect of about thirty per cent, and the asymmetry appears in all latitude zones. Curiously enough, although the Radcliffe proper motions as discussed by van Hoof and Oort show no sign of it, none the less it appears well pronounced in the parallactic motions of the Pulkova reference stars for the Selected Areas which have been reduced to absolute motions by means of the meridian circle observations of Hins. TABLE 4 presents the Pulkova material; taken by itself, the table would not constitute conclusive evidence of a North-South effect, but in conjunction with the McCormick secular parallaxes which are obtained in such

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[16] As a matter of fact, Oort did not use the Radcliffe material for the faintest stars.

[17] Even the McCormick tau-components are more relative than absolute in low latitudes, since actually, before the individual tau-components were derived, the McCormick motions in low latitudes were reduced to absolute by means of the secular parallax of all stars in the region (weight 1.5) as well as by means of the Boss star (average weight 0.7). This would smooth over any local irregularities in the motions.

an entirely different manner, we can no longer regard the effect as accidental.

TABLE 4

SECULAR PARALLAX OF PULKOVA REFERENCE STARS
Mean Pg. Mag. = 13 2

Galactic Latitude	North	South	N-S
1° to 10°	+″ 006± 006	−″ 001± 003	+″.007± 006
11 to 20	+ .015±.005	+ 004±.003	+ .011±.006
21 to 40	+. 011± 004	+ 001± 002	+ 010±.004
41 to 50	+ .016±.002	+ 008± 003	+ .008±.004
51 to 90	+ 013± 001	none	——

The North-South effect (TABLE 4) might possibly be attributed to local systematic errors in the fundamental system, even though, in the McCormick material it is shown independently by the motions in right ascension and by those in declination, no matter whether the motions are on the GC or on the FK3 system.[18] But there is another aspect which seems to give definite proof that the stars in the northern hemisphere are actually nearer, zone for zone and magnitude for magnitude, than those in the southern hemisphere. Thus, if we measure the dispersions of the motions not by means of *relative* peculiar motions but by means of *absolute* mean motions, we find that the groups in the northern hemisphere are more erratic in their motions, *i. e.*, show greater deviations from the predicted motions than the groups in the southern hemisphere. TABLE 5 presents a summary of the material from this point of view. It is seen that the McCormick and the Pulkova material agree in this respect, too.

TABLE 5

PROBABLE ERROR OF ONE MCCORMICK EQUATION

Galactic Latitude	North		South		N-S	
0° to 10°	″.0033±	″ 0005	″.0029±	″.0004	+″.0004±	″ 0007
11 to 20	.0032	.0005	.0043	.0008	− .0011	0009
21 to 40	.0039	.0006	.0024	.0003	+ 0015	0006
41 to 60	.0046	.0006	0030	.0005	+ .0016	.0008
61 to 90	.0058	.0011	.0029	.0007	+ 0029	0013

[18] Williams & Osborne, AJ 47: 43. 1938.

TABLE 5—*Continued*

PROBABLE ERROR OF ONE PULKOVA DETERMINATION OF h/r

0° to 10°	″.013±″.003	″.006±″.001	+″.007±″.003
11 to 20	.011 .003	.008 .001	+ .003 .003
21 to 40	.009 .002	.005 .001	+ .004 .002
41 to 50	.006 .001	.005 .001	+ .001 .001

It remains unexplained, then, why the dispersions of the peculiar motions show the effect so poorly in the McCormick material and not at all in the Leiden-Radcliffe material. Perhaps it is relevant that the zones in which the McCormick reductions to absolute motion were least smoothed by the parallactic motion reduction are the zones which show the North-South asymmetry most clearly. Furthermore, the method of smoothing over the large motions in the Leiden discussions would tend to obliterate any such effect if it existed. Here again, we may hope that additional material will clarify the matter.

MEAN PARALLAXES OF A STARS

Probably fewer assumptions are required in a discussion of the mean parallaxes of A stars than in the case of other spectral groups. For the dispersion in absolute magnitude is not great for A stars; moreover, systems of spectral classifications of faint stars agree with one another better in class A than elsewhere.[19] However even with A stars, a comparison of results is not entirely straightforward, because, as is seen in TABLE 6, Oort used the Groningen spectral grouping and because Stenquist subdivided the material according to the modulus $(m - M)$ instead of according to apparent magnitude.[20] Furthermore, the dispersion in apparent magnitude is rather large in the McCormick grouping. Probably the best argument according to which we may arrange the values of $\bar{p}$ for comparison is the mean value of the modulus $\overline{m - M}$. This involves assuming suitable values for $\overline{M}_{pg}$ which are indicated with asterisks in TABLE 6. Opposite Stenquist are tabulated minimum values of $\underline{\bar{p}}$ corresponding to a minimum average of two magnitudes of interstellar absorption which he concluded was indicated by his material and treatment; actually, Stenquist derived $\bar{r}$, rather than $\bar{p}$. The mean parallaxes obtained from the parallactic motions of the McCormick stars are included for comparison. The probable errors are computed from the internal agreement of the data.

[19] Vyssotsky, ApJ 93: 425. 1941

[20] Van Hoof did not discuss the separate spectral groupings at all.

TABLE 6

Investigation	Spectral Group	Limits of Galactic Latitude	No. of Areas	No. of Square Degrees	No. of Stars	$\overline{m}_{pg}$	$\overline{M}_{pg}$	$\overline{m_{pg} - M_{pg}}$	$\overline{p}$
Oort	A0–A9	0° to ±15°	28	12	85*	11.0	1.3*	9.7*	″.0011±.0002
Oort	A0–A9	0° to ±15°	28	12	170*	12.0	1.4*	10.6*	.0011±.0001
Oort	A0–A9	0° to ±15°	28	12	125*	13.0	1.6*	11.4*	.0010±.0001
McC ($\overline{\lvert\tau\rvert}$)	B8–A3	0° to ±10°	75	42	662	10.2	1.0*	9.2*	.0027±.0003
McC (h/r)	B8–A3	0° to ±10°	75	42	662	10.2	1.0*	9.2*	.0034±.0004
McC ($\overline{\lvert\tau\rvert}$)	B8–A3	±11° to ±20°	47	26	198	10.1	1.0*	9.1*	.0012±.0003
McC (h/r)	B8–A3	±11° to ±20°	47	26	198	10.1	1.0*	9.1*	.0026±.0005
Stenquist	B8–A3	0° to ±20°	24	43	300	9.8	1.1	8.7	⩾ .0030*
Stenquist	B8–A3	0° to ±20°	17	31	180	11.4	0.7	10.7	⩾ .0016*

* These items are approximated by the author. The number of stars in the three magnitude classes of Oort were found from the Bergedorf spectral statistics and the knowledge that the sum of the three groups is 381. The increase of $\overline{M}_{pg}$ with magnitude in the Oort material was also estimated by means of the Bergedorf spectral statistics.

It is immediately evident that there is a systematic difference between Oort's values of $\bar{p}$ and those of Stenquist and McCormick. It has already been shown that the same sort of discrepancy appears between the values of $\bar{p}$ found by Oort and Van Hoof and those found by McCormick for the magnitude groupings in low latitudes. In looking for the cause we note that there are undesirable features in each of the investigations.

The chief weakness of the Stenquist and Oort investigations lies in the small number of samples in low galactic latitudes. In the first case, the number of areas with latitude less than 10° is only fourteen; in the second it is sixteen.

The weak point of the McCormick material is that the average error of observation is relatively large and consequently a small change in the value assumed for it will make a considerable difference in the values of the small parallaxes, such as in the zone ± 11° to ± 20°. For instance, a five per cent increase in the value adopted for the accidental error would be sufficient to place all of the ninety B stars well out beyond infinity! A slightly greater increase would reduce the parallax of the 200 A stars in the zones ± 11° to ± 20° to zero; even so, the mean parallax of all the A stars in the 0° to ± 20° zone would be reduced only from ″.0026 to ″.0022. A slight correction might be introduced to allow for the greater dispersion in apparent magnitude in the McCormick material. This would decrease both of the McCormick values by perhaps ″.0002.[21] But I have not been able to find any reason to reduce them by an amount sufficient to bring about agreement with Oort's values.

According to Oort's computations, his values of $\bar{p}$ would correspond to an average absorption in the galactic plane of one magnitude per kiloparsec although his accidental errors would allow any value up to two and a half magnitudes. The absorption at latitudes ± 10° would be considerably less. The Stenquist and McCormick values of $\bar{p}$ correspond to an average of two magnitudes per kiloparsec throughout the zone from − 20° to + 20°. It is evident that whichever discussion we favor, the average absorption indicated is considerably greater than it is frequently assumed to be.

[21] There is also a very slight reduction on account of a second order effect of galactic rotation to the mean parallaxes derived from absolute tau-components. This effect has been demonstrated by Edmondson (MN 99: 525. 1939). It is possible to show that allowance for this would make practically no difference to the final values, since the McCormick tau-components as actually used are more nearly relative than absolute, cf. note 18 This reduces the already small effect to one third of its value.

SUMMARY

Comparisons are made of the mean parallaxes of stars fainter than tenth magnitude as derived by various methods and from various sources of material. In galactic latitudes greater than 10° the results for twelfth and thirteenth magnitude stars are in satisfactory agreement with one another provided a solar velocity of 20 km/sec is assumed in the reduction of secular parallaxes to the mean parallaxes for all latitude and magnitude groups. In the lowest latitudes, however, there appears to be a systematic difference between the mean parallaxes derived from the Selected Areas and those derived from the McCormick and Cambridge areas. This is probably due to a difference in sampling. As a consequence the space absorption derived from the two latter sources is considerably greater than that derived from the Selected Areas.

THE LUMINOSITY FUNCTION

By W. J. Luyten

From the Observatory of the University of Minnesota

In attempting to determine the form of the luminosity function there must first be considered the question whether or not there *is* a universal luminosity function, *i. e.*, whether or not the distribution of stellar luminosities is the same in the neighborhood of the sun as elsewhere in the galactic system. At present no direct observational evidence is available on this point nor is it likely that any will be forthcoming within the next several decades. The present luminosity function indicates a maximum frequency at about absolute magnitude + 15 photographic; to determine the luminosity function at even so small a distance as 100 parsecs it would thus be necessary to have complete statistical information on the proper motions (down to 0".01) and parallaxes or spectra down to the 21st magnitude for, say, half a dozen areas in the sky of some 30 square degrees each. It is evident that we must now be satisfied with deriving the luminosity function for the immediate vicinity of the sun and be careful not to ascribe any properties of universality to this function.

Any proper determination of even this local luminosity function must be based on the three following points:

(*a*) Derivation of the frequency of proper motions, if possible down to the eighteenth magnitude and to 0".2 annually.

(*b*) Determination of the mean parallax as a function of apparent magnitude and proper motion.

(*c*) Determination of the dispersion of the true parallaxes around this mean.

The writer's survey for large proper motions covers 94 per cent of the southern hemisphere and is complete down to 14.5. Data for stars between 14.5 and 16.5 were derived from plates covering only 6 per cent of the southern hemisphere. In addition to the southern survey more than 100 pairs of plates have been blinked at Minnesota by the writer and his collaborators. Using this survey to supplement those made by Wolf and Ross we find that, roughly, five-sixths of the northern hemisphere has now been blinked. There is, however, a woeful lack of homogeneity between these surveys—in limiting

magnitude, completeness over the plate, and in accuracy of the motions measured. Any estimates that can now be made for the total number of proper motion stars in the northern hemisphere must be considered as extremely provisional, therefore. There are still indications that the northern hemisphere is richer in faint stars with very large proper motions, as is shown by the data in TABLE 1 but it would be premature to draw conclusions until more information is available. TABLE 2 shows the numbers of stars with proper motion in excess of

TABLE 1

NUMBER OF PROPER MOTION STARS IN NORTHERN AND SOUTHERN HEMISPHERES

	North	South
$\mu > 1''.4$ $10.6 < m < 14.5$	36 (known) 44 (est. total)	25

0″.5 now known, and the total numbers predicted in both the northern and southern hemispheres. For stars fainter than 14.5 the number in the northern hemisphere has been assumed equal to that in the southern.

For motions between 0″.2 and 0″.5 annually estimates have been made by the writer for the area south of declination — 60 where all motions found in the survey have been measured. Since then, measures have likewise been completed for 33000 stars between — 60

TABLE 2

	Known	Still to be found	Estimated total
$\mu > 1''$ $m < 14.5$	138 S 126 N	4 S 22 N	142 S 148 N
$0''.5 < \mu < 1''$ $m < 14.5$	545 S 513 N	23 S 77 N	568 S 590 N
$\mu > 0''.5$ $m < 14.5$	1322	126	1448
$\mu > 0''.5$ $16.5 > m > 14.5$	172 S 103 N	610 S 679 N	782 S 782 N
	275	1289	1564
$\mu > 0''.5$ $m < 16.5$	1597	1415	3012

and — 40, and a discussion is in progress. The numbers obtained for these areas are deemed to be accurate down to 14.5 and fairly reliable to 16.5. Down to 13.5 the writer's survey agrees fairly well with and thus confirms the results obtained at Groningen, Greenwich, Radcliffe, and McCormick.

For stars fainter than 14.5 a comparison with the Mt. Wilson survey of selected areas only is available. For this survey van Maanen states that it should be virtually complete for motions larger than $0''.1$ annually. If the writer's survey of the south polar area is anywhere near representative for the whole sky van Maanen appears to have missed about 50 per cent of the stars with motions larger than $0''.10$.

Concluding we find that the situation for stars brighter than 14.5 and with motions larger than $0''.5$ annually may be considered satisfactory, but that this is not the case for stars either fainter or with smaller motions. One of the most urgent desiderata is the blinking of plates showing stars down to the 18th magnitude in order that we may arrive at greater certainty concerning the number of stars in the sky between 14.5 and 16.5 or even 18.5 with proper motions larger than $0''.2$ annually.

Information concerning points (*b*) and (*c*) is obtained from a discussion of the trigonometric parallaxes of stars of large proper motion. A good deal of uncertainty still exists on both points especially when applied to stars with motions less than $0''.5$. As an illustration we may use the following: suppose we wish to determine statistically the numbers of stars of each absolute magnitude nearer than 10 parsecs and are considering the contribution made by the stars between 17.5 and 18.5 with motions between $0''.2$ and $0''.3$ annually, or, $m = 18.0$, $\mu = 0''.25$. For these stars the absolute magnitude probably lies between 13.5 and 14.0. Those stars nearer than ten parsecs hence deviate from this mean by 4.0 to 4.5. At present the dispersion in the parallaxes is uncertain and its extreme range may be estimated as between 0.25 and 0.32 in log p, corresponding to 1.25 to 1.6 in M. TABLE 3 shows the respective percentages of these stars with $m = 18$, $\mu = 0''.25$ found to lie nearer than 10 parsecs as based upon these four limiting possibilities.

TABLE 3

PERCENTAGES OF STARS WITH $m = 18.0$, $\mu = 0''.25$ NEARER THAN 10 PARSECS

	$\overline{M} = 13.5$	$\overline{M} = 14.0$
$\sigma_p = 0.25$	0.017%	0.070%
$\sigma_p = 0.32$	0.256%	0 615%

Since the total number of stars of this kind in the sky is probably in the neighborhood of 18000 the actual contribution of the stars nearer than 10 parsecs may lie almost anywhere between 3 and 100. The limits chosen here are extreme and in actual practice it would probably be possible to narrow down the range considerably but the case may be used to illustrate the point. What is even more disconcerting is the fact that the actual dispersion in true parallax, or rather in log $p/\bar{p}$ almost certainly does not follow a normal error curve—the corresponding distribution of velocities would be dynamically unexplainable. Yet some analytical form for this function has to be adopted in order to make it amenable to use in the present instance. Assuming a normal error curve in log $p/\bar{p}$ implies an extremely skew distribution in log T, as I have pointed out before. To take a concrete case, assume $\sigma_M = 1.5$; then the numbers of stars deviating between 3 and 4 units from this mean absolute magnitude amount to 0.7 per cent on both sides. Actually, however, those stars fainter than the mean absolute magnitude are confined to the limits between 0.158 and 0.251 of the distance corresponding to the mean absolute magnitude, whereas those on the bright side lie between four and six times this same distance; *i. e.* the latter occupy a space 13,500 times greater than the former.

To illustrate how well the various observational data agree with each other within the framework of our present assumptions the following calculations and comparisons may serve.

Table 4 shows the distribution of the absolute magnitudes of the 154 stars whose trigonometric parallaxes exceed 0″.100, as compared with the numbers of stars expected within this region of space on the basis of the writer's luminosity curve. (Publications of the Astronomical Observatory, University of Minnesota vol. 2, p. 152. 1939.)

Table 4

M	N(obs)	N(calc)	M	N(obs)	N(calc)
<1.5	2	2	10	7	29
2	2	3	11	18	34
3	2	4	12	22	38
4	7	6	13	16	42
5	10	9	14	9	46
6	10	12	15	8	46
7	15	16	16	3	40
8	13	20	17	2	31
9	8	24	18	1	19

TABLE 5

M	N(obs)	N(calc)	N(obs, $p > 0''.2$)
< 7.5	48	52	6
7.6–10.5	28	73	6
10.6–13.5	56	114	10

Condensing the data into those given in TABLE 5 we find, as anticipated that the agreement is satisfactory for $M < 7.5$, and that few stars brighter than apparent magnitude 8 and with parallaxes larger than $0''.1$ remain undiscovered. The sudden drop for those with M between 7.6 and 10.5 is surprising and may possibly be real as it shows in the stars nearer than 5 parsecs as well. This same drop in the frequency of absolute magnitude had been announced by van Rhijn (GP 47 Table 6) and it actually shows in all four provisional luminosity curves derived by the writer (Bruce Proper Motion Survey No. 5, the Stars of Large Proper Motion and the Luminosity Function, pp. 150–153) but the curve finally adopted had been smoothed; this now appears to have been an error.

TABLE 6

m \ μ	$0''.5$–$1''.0$	$1''$–$2''$	$2''$–$4''$	$> 4''$
≤4.5	52 (1) 44 – 15	18 13 7	5 3 3	2 1 0
4.5– 7.5	230 (51) 156 (12) 96	50 (2) 32 30	11 6 5	3 2 4
7.5–10.5	760 (75) 356 (35) 271	140 (7) 66 37	28 12 8	7 3 5
10.5–13.5	1710 (515) 647 (79) 485	278 (18) 104 (1) 114	45 17 16	8 4 1
13.5–16.5	2150 (615) 834 (138) 1358 : :	390 (30) 127 (2) 183 : :	48 15 16	7 2 2

If, for these 154 stars we calculate the relation between H and M, where $H = m + 5 + 5 \log \mu$, we find:

$$M > 7.0 \quad \overline{H} = M + 3.75 \text{ (42 stars) with a dispersion of 1.6}$$
$$7.1 > M > 12.0 \quad = M + 4.56 \text{ (65 stars) with a dispersion of 1.4}$$
$$12.1 > M \quad = M + 4.56 \text{ (48 stars) with a dispersion of 1.4}$$

As seen above, the 250 odd stars nearer than 10 parsecs which are as yet undiscovered should virtually all be fainter than $M = 7$. These same stars may also be expected to have smaller tangential velocities than those now known. Consequently the ultimate value of $H - M$ for all stars fainter than $M = 7$ will be considerably less though it would appear unlikely that it could come down to the value of 3.75 for the stars brighter than 7.0 absolute, since in that case all the undiscovered stars nearer than 10 parsecs should have an average tangential velocity of no more than 22 km/sec.

In any case there are strong indications that the regression of H on M which even now shows no progressive increase of T with a decrease in luminosity for M fainter than 7 ultimately may be found to show little or no such progression over the entire range of absolute magnitude. In other words, stars of small tangential velocity appear to be very numerous even among stars of low luminosity.

Assuming as extreme cases that the regression of H on M for all stars nearer than ten parsecs lies between the two following limits:

(a) $\overline{H} = M + 3.8 \pm 1.6$ for M brighter than 7

$\overline{H} = M + 4.5 \pm 1.4$ for M fainter than 7 and

(b) $\overline{H} = M + 3.8 \pm 1.33$ for all stars

we may attempt to check our several assumptions by using them to calculate the distribution of large proper motions for stars brighter than 16.5 m_{pg}. The results of this are shown in TABLE 6 where in each square are given: on the first line, the total calculated number of stars derived from the assumptions that the luminosity function is a constant in space and that above assumption (a) holds true. On the second line, the total number of stars similarly calculated on the basis of assumption (b). On both lines, the numbers in parentheses indicate the contributions made to the total numbers by stars more distant than 50 parsecs. On the third line, the observed numbers, *i. e.*, for stars brighter than apparent magnitude 10.5 the actually known numbers in both northern and southern hemispheres, for

stars between 10.5 and 13.5 the estimated totals for northern and southern hemispheres combined, and for stars between 13.5 and 16.5 twice the estimated totals for the southern hemisphere alone.

TABLE 7 gives, further, the actually observed total numbers of stars of determined photographic apparent magnitude (second column), the total number of such stars contributed by the stars nearer than 50 parsecs (third column), and similarly the number contributed by the stars between 50 and 316 parsecs (fourth column).

TABLE 7

m_{pg}	A_m(obs)	A_m $r < 50$	A_m $50 < r < 316$
4.5	600	425	166
5	1150	460	1300
6	3150	660	6350
7	8600	910	25400
8	24000	1260	69250
9	64500	1660	115400
10	166000	2100	166000
11	422000	2600	227500
12	1000000	3100	326000
13	2500000	3800	414000

It may be noted that all calculated numbers in the first line in each square of TABLE 6 are much too large, some by a factor of more than 2 : 1 and only those in the second line, which we had believed to represent an actual extreme limit begin to approach the right order of magnitude. In TABLE 7 the agreement is poor even for stars as bright as $m = 5$ which suggests that even at $r = 50$ parsecs the star density begins to be appreciably less than near the sun. The agreement of the data beyond $m = 9$ does not mean much as here the contribution made by stars further distant than 316 parsecs—which is neglected here—becomes considerable. In addition it appears likely that the frequency of stars brighter than absolute magnitude 7 is less than that indicated by the writer's luminosity curve.

TABLE 6 shows a calculated total number of stars brighter than 16.5 and with motions larger than 2″ annually of 65 (assumption *b*), and an estimated total number of 60, of which 50 are now actually known. For 45 of these parallaxes are known and among these we have:

TABLE 8

DISTRIBUTION OF STARS WITH $\mu > 2''$

Distance	Known stars	No. calculated
0–10 parsecs	35	51
>10	10	14

The calculated and observed distribution of tangential velocities for all stars nearer than 10 parsecs is shown in TABLE 9.

TABLE 9

H-M	Observed	Calculated from H-M = 3 8 ± 1 33
−1	0	0 3
0	1	2 7
1	4	15
2	9	53
3	28	105
4	45	124
5	37	87
6	19	36
7	8	8
8	2	1.2
9	1	0.1

It would thus appear that the calculated numbers, which we thought to be based upon an extreme assumption as to smallness of tangential velocity and its dispersion are not yet extreme enough, except perhaps for the very largest velocities where the calculated numbers are slightly too low. It appears likely that the real H-M frequency curve is skew, perhaps with a modal value of + 3 agreeing with our present normal curve in total numbers of stars with H-$M < 6.5$ but giving appreciably smaller frequencies for $3.5 < H$-$M < 6.5$.

Further parallax observations are required, especially for stars of smaller proper motions, at least down to 0″.2 annually, and hence a first desideratum is the determination of accurate spectral classes for as large a number of stars as possible down to at least 16.5. The real distribution of velocities cannot become known until at least several hundred more radial velocities of absolutely faint stars have been determined.

All of the foregoing analysis applies only to stars brighter than + 15 absolute, at least. For those fainter than this limit almost

nothing is known at present; the contribution made by these stars to the total light or total mass is insignificant. It is entirely possible that the frequency of stars as faint as + 18 absolute or fainter is much greater than that indicated by the writer's luminosity curve.

Summarizing we conclude that any or all of the following may be true:

(*a*) The luminosity curve may not be a smooth curve but show "dips" in frequency as e. g. around + 7 to + 11.

(*b*) The total number of stars brighter than $M = + 15$ may be somewhat less than that indicated by the writer's luminosity curve.

(*c*) The star density may be getting appreciably less even at distances from the sun of no more than 50 parsecs.

(*d*) The mean tangential velocity of the stars in space in the neighborhood of the sun must be much less than that now found, and may be no more than 25–30 km/sec.

(*e*) The true form of the frequency curve of tangential velocities is probably skew in log T, showing a mode at some value for H-M perhaps no greater than 20 km/sec.

(*f*) There may be no universal luminosity function at all but the mixture of stars of different absolute magnitudes may differ radically over even comparatively small distances.

THE MAGNITUDE SCALE TODAY

By Frederick H. Seares

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When the international magnitudes of the North Polar Sequence (NPS) were adopted at the Rome conference of 1922[1] there was reason to believe that future data would scarcely change the photographic scale in the region above the sixteenth magnitude. There was also evidence that the photographic and photovisual scales were mutually consistent to at least the eighteenth magnitude. Beyond this limit the results admittedly were less certain. In reviewing the situation today I shall be more interested in the present state of these fundamental standards than in the numerous uses to which they have been put. It is convenient first, however, to say something about a recent extension of the standards.

It is not always easy to transfer the system of the original standards to other parts of the sky. The bright stars especially are too few in number and their color system is badly defined. To remove this defect and at the same time to supply abundant data for determining the complicated plate corrections required by photographs made with large-field cameras, the International System has been extended to about 2000 neighboring stars brighter than the twelfth photographic magnitude.[2] The results are based partly on existing catalogs but mainly on recent photographs obtained by Dr. F. E. Ross of the Yerkes Observatory. The precision is usually comparable with that of the NPS itself, the average mean error (exclusive of zero point) of a catalog magnitude being ± 0.02, and, under favorable conditions, scarcely in excess of ± 0.01 mag. The color system seemingly agrees with the ill-defined system of the bright NPS stars within $0.01C$ ($C =$ color index), although, owing to spectral peculiarities, the relations for early A-type stars are less certain.

Deviations in zero point over the polar region of 10° radius rarely exceed 0.01 mag. This estimate depends on comparisons of independent determinations from overlapping plates, on closing errors for different zones of declination, and on comparisons with existing catalogs after reduction to the International System. For example,

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[1] Trans. I. A. U. 1: 71. 1922.

[2] Seares, Ross, & Joyner, "Magnitudes and Colors of Stars North of +80°", Carnegie Inst. Publ. No. 532. A preliminary edition, the "Provisional Catalogue," including photographic magnitudes for all the stars and photovisual values for 331 of them was issued in mimeograph form in 1935.

the deviations of the individual photographic catalogs from the new Polar Catalog run in right ascension as shown in TABLE 1. The stars used, 20 to 30 for each difference, in declinations 80°–86°, are mostly brighter than magnitude 8.0. Narrower zones of declination —and the photovisual data as well—show similar results. The deviations for the mean of the six catalogs (third line from the bottom of TABLE 1) are in harmony with the estimate given. These details also bear on a point of importance to be mentioned presently.

TABLE 1

MT. W. POLAR CATALOG *minus* INDIVIDUAL CATALOGS
(*Pg* MAGNITUDES, DEC. 80°–86°, UNIT = 0.01 MAG.)

Catalog	$2^h.0$	$6^h.0$	$10^h.0$	$14^h.0$	$18^h.0$	$22^h.0$
Greenwich	−1.8	−1.5	−3.3	+2.2	+2.3	+3.9
Simeis	−0.6	−2.7	+0.5	−1.1	+3.7	+0.4
Harvard-Payne	+2.0	0.0	−1.5	−3.3	+1.5	+3.1
Leiden-de Sitter	−1.8	+1.0	−0.6	+1.2	+0.3	+0.3
Göttingen	−3.4	+1.3	+7.8	−0.7	−4.4	−2.2
Yerkes-Parkhurst	+1.1	+2.5	+3.4	+2.8	−4.5	−3.0
Polar Cat. − Mean Cat.	−0.6	0 0	+1.1	+0.8	−1.1	+0.5
Polar Cat. − Hass.	−4.0	−1.7	+0.2	+1.0	+3.5	+0.9
Hass. − Mean Cat.	+3.4	+1.7	+0.9	−0.2	−4.6	−0.4

The results just described represent only an extension to other stars of the scales and color system defined by the 1922 standards.[3] They do not provide any improvement of the system itself, although they have led to some decrease in the accidental errors affecting individual standards. The reduction-curves used for the extension gave many additional values for the magnitudes of these stars; and color indices found from exposure ratios could be used with the data on magnitudes for an adjustment satisfying the condition $Pg - Pv = C$.[4]

[3] Magnitudes for other supplementary stars, based on the NPS standards, have been determined by **Dyson, Sir F.**, Photographic Magnitudes in Kapteyn's Selected Areas. Greenwich. 1931. Includes *Pg* results for 395 stars within 1° of the pole; magnitudes 9–15. The color system needs revision. **Armeanca, J.**, Göttingen Veröff. No. 35; Zeit. Ap. 7: 78, 1933. *Pg* and *Pv* magnitudes for 260 stars, 12.5–16.2 photographic. **Ross, F. E.**, ApJ 84: 241, 1936. *Pg* and *Pv* magnitudes for 500 stars within 2° of the pole, 9–13.7 photographic. **Wallenquist, Å.**, Östen Bergstrand Festskrift. p. 39. 1938. *Pg* and *Pv* magnitudes of 16 supplementary stars within 30′ of star 5s, 10.6–13.5 photographic.

[4] The revised magnitudes and colors thus derived for 30 NPS stars are given in Mt. W. Contr. No. 587, table 1; ApJ 87: 257. 1938.

As for tests of the scales themselves, a good deal of evidence has been accumulated since the adoption of the Rome Report.[1] In particular, a general confirmation of the photovisual scale within the interval 2.1–12.1 was supplied by Hassenstein's reduction of the visual measurements made with a Zöllner photometer by Müller, Kron, and Kohlschütter.[5] Aside from a deviation of 0.07 mag. for a single group of stars, the scale differences throughout the 10-magnitude interval did not exceed 0.05 mag. It is likely, however, that part of these differences arose from small systematic errors in the Potsdam measures, for use of the Greenwich effective wave lengths in preparing the Polar Catalog just described showed again the high consistency of the photographic and the photovisual scales.

A more rigorous test is supplied by the photoelectric measures of Stebbins and Whitford.[6] The essential results are shown in the fourth and fifth columns of TABLE 2, in the form of corrections to the revised

TABLE 2

SCALE COMPARISONS FOR NPS STARS

NPS Stars	Pg_r	Pv_r	Stebbins Red. *minus*		Hass. Orig. *minus*		Hass. Adj. *minus*	
			Pg_r	Pv_r	Pg_r	Steb. Red.	Pg_r	Steb. Red.
1	4.39	4 39	−0.13	−0.15	−0.04	+0.09	−0.01	+0.12
2	5.22	5 30	− .13	− .13	.00	+ .13	+ .03	+ .16
3	5.76	5.58	− .08	− .03	+ .03	+ .11	− .01	+ .07
4	5.95	5.82	− .08	− .11	.00	+ .08	+ .03	+ .11
5	6.46	6 46	− .05	− .07	+ .05	+ .10	+ .01	+ .06
2s	6.50	6 30	.00	+ .01	+ .04	+ .04	.00	.00
3s	6.64	6 33	+ .01	+ .04	+ .07	+ .06	+ .03	+ .02
1r	6.67	5.08	− .01	− .01	+0.02	+0.03	−0.02	−0.01
6, 7, 2r, 8	7.68	7 28	00^{0}	+ .01^{0}				
9, 3r, 10, 4r	9.05	8.43	+ .01^{2}	− .02^{0}				
11, 12, 5r, 4s	10.08	9 45	+ .01^{5}	+ .02^{0}				
13, 6r, 14, 7r	10.75	10 00	− .02^{5}	.00^{0}				
5s, 15, 6s, 8r, 16	11.35	10.66	−0.00^{8}	−0.02^{0}				
System. Diff.*			−0.00^{1}	−0 00^{1}	+0 02^{1}		+0.00^{8}	
Average Diff.*			±0.01^{7}	±0.03^{0}	±0.03^{1}		±0.01^{8}	

* Values in the fourth and fifth columns do not include stars 1–5.

values (Pg_r and Pv_r) of the NPS standards.[4] Differences are given individually for the first eight stars of the Sequence and thereafter for groups of four or five, as indicated by the first column of the

[5] Potsdam Pub. 26 (2) (No. 85): 1927. For details of the comparison see Mt. W. Contr. No. 431; ApJ 74: 131. 1931, especially tables 3 and 5.

[6] Mt. W. Contr. No. 586; ApJ 87: 237, 1938. The comparison by F. H. Seares appears in Mt. W. Contr. No. 587; ApJ 87: 257, 1938.

table. For the comparison the photoelectric magnitudes (Pe) had first to be reduced to the color systems of the Pg_r and Pv_r standards. The formulae used were

$$Pg_p = Pe - 0.12 + 0.20C_r, \tag{1}$$

$$Pv_p = Pe - 0.12 - 0.80C_p, \tag{2}$$

in which C_p is the color index on the International System derived from the photoelectric color C_2 of Stebbins and Whitford.[7]

For the 5-magnitude interval from star 2s downward the systematic relations are entirely satisfactory; there is no trace of scale divergence and the average differences in the magnitudes are only ± 0.017 and ± 0.030 mag., respectively. The larger difference for the photovisual series indicates, not increased observational errors, but a dispersion in the values of C_p relative to those of C_r unaccounted for by such errors.

For the first five stars, however, the differences are wholly inadmissible. The internal agreement of the data seems to exclude the possibility of any serious error in the NPS standards; nor can we suppose that the very precise measures by Stebbins and Whitford are affected by errors as large as these differences. The proper inference seems to be that the two series of magnitudes are measurements of different things and that the reduction of the photoelectric magnitudes to the NPS color system is for some reason incomplete. For example, the five discordant stars are early A's and therefore presumably affected by strong hydrogen absorption in the ultraviolet. Photographic magnitudes measured with a reflecting telescope (the basis for the standards) include this region and must be influenced by the absorption. The photoelectric results by Stebbins and Whitford, on the other hand, are unaffected; and unless allowance is made for this circumstance, the results for A-type stars should differ in the direction actually observed, the discordance being carried over into the photovisual comparison through the use of formula (2). There is some positive evidence in support of this hypothesis, but a few observations made by Stebbins and Whitford with a photocell which reaches into the critical region agree with their earlier results.

The still more recent photoelectric magnitudes by Hassenstein[8] supply evidence on the scale but do not at once settle the question

[7] If the value $C_r = Pg_r - Pv_r$ is used in formula (2), the differences $Pv_p - Pv_r$ become numerically equal to the values of $Pg_p - Pg_r$ found with (1) and the test of the Pv scale fails. Independently determined colors, for example C_p, must therefore be used in (2).

[8] Astr Nachr 269: 185. 1939. The list includes 102 stars north of +75° declination, brighter than photographic magnitude 6.7.

as to the influence of spectral peculiarities: the wave-length interval covered by the observations is not stated. Hassenstein found the color system of his magnitudes to be identical with that of the Mt. Wilson Provisional Catalog (and hence with that of the Polar Catalog[2]); but he also found less agreeable features, namely, a scale divergence of 2 per cent, a surprisingly large accidental difference of ± 0.034 mag. per star, and a zero-point deviation depending on right ascension.

Examination of the individual differences (from here on, relative to the Polar Catalog) shows that a line across the polar cap near the pole, roughly along RA 9^h to 22^h, divides the 40 stars common to the two lists into groups of 24 and 16 stars, respectively. In the first group there are but two positive differences, in the second only a single negative difference. For the 36 stars in declinations 80°–86° the mean differences for 4^h intervals of right ascension are given in the last line but one of TABLE 1.

The question now is whether these irregularities originate in the Polar Catalog or in the magnitudes of Hassenstein. Subtraction of the differences from those in the upper part of the table eliminates the Polar Catalog and gives differences of the form Hassenstein *minus* individual catalog. If the irregularities are in the Polar Catalog, the zero-point agreement should thereby be improved. Actually the root mean-square deviation is increased (from 0.029 to 0.034 mag.), whence it is inferred that most of the trouble lies in the photoelectric magnitudes. Again, comparison of the last line of TABLE 1 with the second line above shows directly that the Polar Catalog agrees better with the mean of the individual catalogs than does Hassenstein (root mean-square deviations, 0.009 and 0.025 mag., respectively); and since the six catalogs involved are independent, probability assigns the error to Hassenstein.

In attempting to remove this irregularity, probably all that is justified is the application of mean zero-point corrections (-0.04 and $+0.03$ mag., respectively) to the two groups of stars showing systematic deviations. With no other change in Hassenstein's magnitudes, their relation to the Polar Catalog becomes that shown in TABLE 3. The 2 per cent scale divergence has disappeared and the accidental differences have been reduced to the more reasonable value of ± 0.019 mag. The relative color equation, as Hassenstein found, is inappreciable. The data of TABLE 3 thus confirm the photographic scale of the bright stars in the Polar Catalog in a region where the transfer

TABLE 3

MT. WILSON POLAR CATALOG (*Pg*) *minus* HASSENSTEIN PHOTOELECTRIC

Hassenstein *Pe*	SD	AD	No. Stars	C	SD	AD	No. Stars
4 35	+0 01		1	−0 13	+0 009	±0 016	8
5 31	000	±0 015	4	+0 08	+ 010	021	11
5 75	+ 002	022	8	0 26	− 016	019	7
6 14	+ 009	024	9	0 74	− 012	028	6
6 39	− 002	024	10	1 30	+0 011	±0 014	8
6 61	0 000	±0 008	8				
All	+0 002	±0 019	40		+0 002	±0 019	40

from the NPS standards involved much difficulty and thereby supply an important test.

The results from Hassenstein's measures of NPS stars are shown separately in the last four columns of TABLE 2. Deviations from the Pg_r standards and from the reduced values of Stebbins and Whitford are given for Hassenstein's original magnitudes and for the values adjusted for zero point. The "original" differences show clearly the influence of zero-point error, which has been removed by the corrections applied. Those relative to Pg_r, especially the adjusted values, are free from the discordance for stars 1–5 shown in the fourth column of the table. With allowance for algebraic sign this discordance appears to its full amount, however, in the comparison with Stebbins and Whitford given in the last column and is also clearly present in the uncorrected differences in the third column from the end.

On the showing of the present evidence there seems to be little doubt that the NPS standards represent a consistent and homogeneous series of magnitudes whose systematic and mean accidental errors, to the twelfth magnitude at least, do not exceed 0.01 or 0.02 mag. The tests afforded by the photoelectric measurements are the more valuable because the comparison is with results obtained by a method entirely independent of photography.

Below the twelfth magnitude we have an additional test based on an independent determination of the photographic scale. In preparing the Mt. Wilson Catalog of Selected Areas[9] the scale was established independently in each of 139 fields, 37 of which were connected directly with the NPS standards by polar comparisons made

[9] Carnegie Inst Publ. No 402. 1930

primarily to determine the zero points. Each of these plates could, however, be used for a comparison of the NPS scale with that of the Area. Means of about 1600 differences in the 37 Areas, distributed over the magnitude interval 11.5–16.5, reveal no relative scale error exceeding 0.01 mag.[10] Similar means for groups of 9 or 10 Areas, although not so small, are still generally satisfactory.

Below magnitude 16.5 there is no independent test of the NPS scales other than that of mutual consistency shown by the color indices derived from exposure ratios. This interagreement, as already stated, extends to about the eighteenth magnitude.

In the Selected Areas, however, there is reason for confidence in the photographic scale to 17.5 or 18.0, at least in the mean scale for two or more Areas. The polar comparisons just described extend down to 16.0–16.5, the middle of the interval covered by the scale determinations in the Areas—a point where the accuracy is greatest. Since the agreement with the NPS scale for the upper half of this interval is satisfactory, the scales in the Areas should be normal for at least another magnitude downward. With rare exceptions, the safe limit for the Areas should therefore be at least 17.5.

Whenever magnitudes in the Selected Areas are to be used as standards for exacting work, two points should be noted, however, first, for greater security of zero point, choose as comparison fields Areas which have been connected directly with the NPS; second, to minimize the influence of accidental and residual systematic errors, use at least two Areas as reference fields.

Finally, there remains the matter of very faint standards, now important for many investigations, especially those on extragalactic nebulae. The results at present, in a few isolated fields, are fragmentary. To relieve a pressing need, Dr. Baade has in hand at Mount Wilson a program which will extend the photographic scales and supply photovisual scales in every third Selected Area of the zone at $+15°$ declination. The magnitude limits will be 21 and 20, respectively.

[10] Carnegie Inst. Publ No. 402. XLVI.

THE STELLAR DISTRIBUTION IN HIGH AND INTERMEDIATE LATITUDES

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THE GALACTIC POLAR CAPS

In 1932 Oort[1] published an important paper on the stellar distribution and the distribution of linear velocities perpendicular to the galactic plane. It was the main purpose of Oort's study to extend the research begun by Kapteyn[2] in which a first attempt was made to correlate the density and velocity distribution perpendicular to the plane. For our purpose the most significant results in Oort's paper are his data on the density distribution for various spectral types.

During the nine years that have elapsed since the publication of Oort's paper several important additions have been made to the basic observations that bear upon our problem. Before proceeding with the analysis we shall investigate briefly what observations are now at our disposal.

The Data of Observation

STARCOUNTS

The counts to various limits of apparent magnitude published by van Rhijn[3] represent the most homogeneous data for the galactic polar caps. Because of a lack of reliable faint magnitudes the counts for the selected areas south of $\delta = -15°$ are less trustworthy than those for the northern areas. Since the declinations of the north and south galactic poles are respectively $+28°$ and $-28°$ we have used van Rhijn's counts only for the north galactic polar cap.

To supplement van Rhijn's material we have made use of the counts at the north galactic pole published by Malmquist[4] and checked these values against the averages derived by Oort.[1] We note that van Rhijn's values of $\log A(m)$† are somewhat small for $m = 9.5$

* Holder of a Royal Society of Canada Fellowship, 1940–1941.

[1] BAN No 238. 1932.

[2] ApJ 55: 302. 1922; Mt. Wilson Contr. No. 230.

[3] Groningen Publ No. 43. 1929.

[4] Stockholm Ann 12. No 7. 1936.

† $A(m)$ being the number of stars per square degree between photographic magnitudes $m - \frac{1}{2}$ and $m + \frac{1}{2}$.

to $m = 12.0$. This is in line with a result of Lindsay and Bok,[5] who showed that there are definite indications of a systematic error of $0^m.3$ in the magnitude system of van Rhijn's tables.

The curve in FIGURE 1 gives the adopted values of log $A(m)$ for the north galactic pole. These values are tabulated in TABLE 1.

TABLE 1

m	log $A_{90}(m)$	m	log $A_{90}(m)$
6.0	8.65	13.0	1 25
7.0	9.10	14.0	1 52
8.0	9.52	15.0	1.80
9.0	9.95	16.0	2.08
10.0	0.30	17.0	2.31
11.0	0.62	18 0	2 57
12.0	0.95		

MEAN PARALLAXES

The basic data for the mean parallaxes at the north galactic pole have been taken from investigations by van Rhijn and Bok,[6] van Rhijn and Schwassmann,[7] van de Kamp and Vyssotsky,[8] and Oort.[9] The individual values of the mean parallaxes, in seconds of arc and all reduced to the galactic pole and to photographic magnitudes, have been listed in TABLE 2. The adopted values are in the last column.

TABLE 2

m_{90}	Oort	GP 45	van de Kamp and Vyssotsky	van Rhijn and Schwassmann	Adopted
9.0	″.0098	″.0090			″.0090
10.0	.0073	.0066	″.0053	″.0056	.0063
11.0	.0054	.0050			.0048
12.0	.0040	.0037	.0033	.0035	.0036
13.0	.0030	.0028			.0028
14.0	.0022				.0022
15.0					

[5] H.A. **105**. No. 14. 1937.
[6] Groningen Publ. No. 45. 1931.
[7] Zeit. Ap. **10**: 161. 1935.
[8] AJ **46**: 9. 1937.
[9] BAN No. 290. 1936.

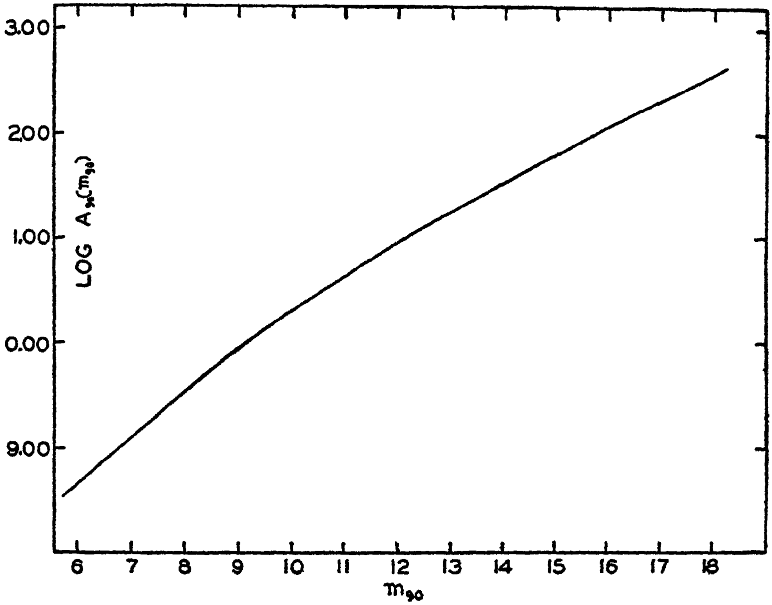

FIGURE 1.

SPECTRAL DATA

Malmquist[10] has published some preliminary data on the distribution of spectral types at the north galactic pole. His results have been compared with some unpublished material for the same part of the sky which was kindly furnished by Miss Cannon and Mrs. Mayall. The agreement was quite satisfactory. The block diagrams in FIGURE 2 represent the accepted distributions of the spectral types for various magnitudes at the north galactic pole.

THE GENERAL LUMINOSITY FUNCTION IN THE GALACTIC PLANE

Van Rhijn[11] has published the most complete version of the general luminosity function, which represents in the galactic plane the number of stars per unit volume for successive intervals of absolute magnitude between $M = -6.0$ and $M = +14.0$. For the stars fainter than $M = +14.0$ Luyten[12] has more recently given the luminosity function in which the results from his search for large proper motions have been used. Both sets of data are reproduced graphically in

[10] Trans. I.A.U. 6: 460. 1938.
[11] Groningen Publ. No. 47. 1936.
[12] Minnesota Publ. 2. No. 7. 1939.

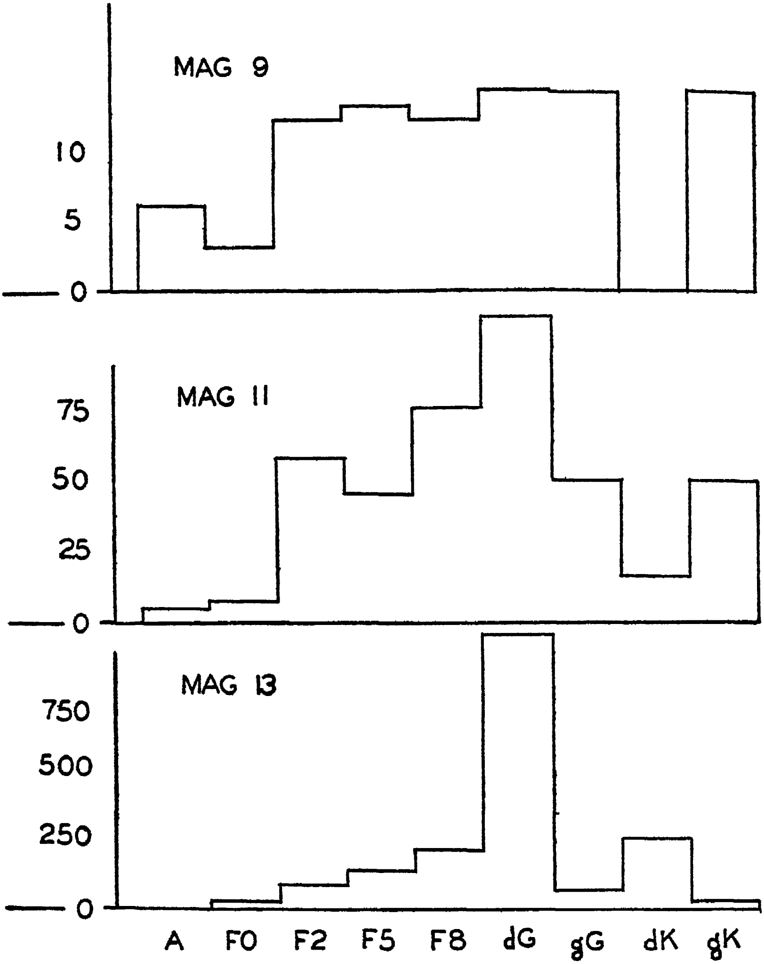

FIGURE 2.

FIGURE 3, where the curve represents the adopted values; see also TABLE 3. We have adopted van Rhijn's values for the stars of $M = +6.0$ and brighter and Luyten's for the fainter stars. We note that the differences between Luyten and van Rhijn are in the direction that van Rhijn has apparently underestimated the number of absolutely faint stars between $M = +6.0$ and $M = +12.0$

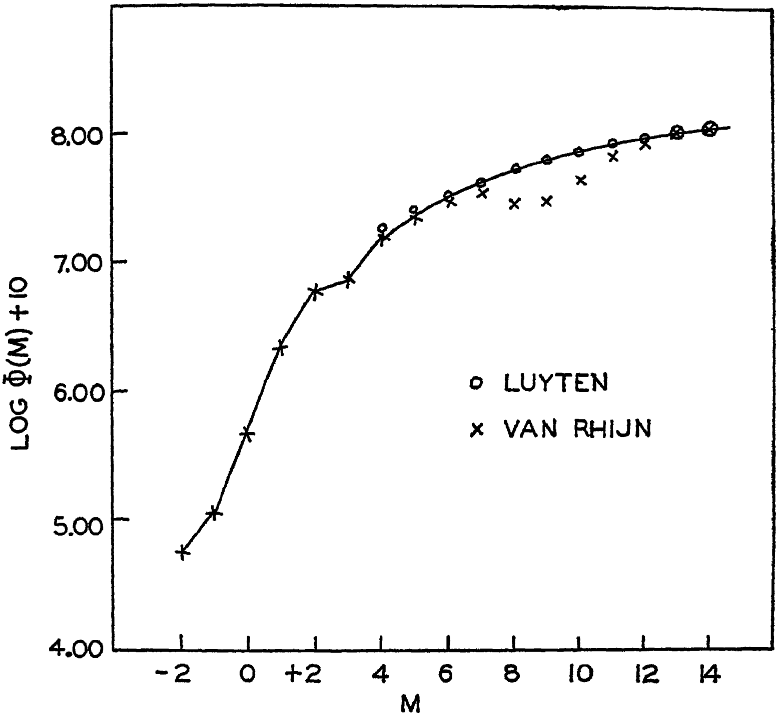

FIGURE 3.

TABLE 3

TABULATED QUANTITIES ARE LOG $\varphi(M) + 10$

M	Adopted	van Rhijn	Luyten
−2	4.75	4.75	
−1	5.07	5.07	
0	5.68	5.68	
+1	6.34	6.34	
+2	6.77	6.77	
+3	6.86	6 86	
+4	7.19	7.19	7.24
+5	7.35	7 35	7.40
+6	7.50	7.49	7.52
+7	7.62	7.53	7.62
+8	7.72	7.46	7.72
+9	7 80	7.49	7.80
+10	7 88	7.64	7.88
+11	7.93	7.81	7.93
+12	7.98	7.97	7.98
+13	8 02	8.01	8.02
+14	8.06	8.06	8.06

VARIATIONS IN THE LUMINOSITY FUNCTION WITH HEIGHT ABOVE THE GALACTIC PLANE

In the present section we shall investigate the rate of decrease in the star density in a direction perpendicular to the galactic plane for different values of the absolute magnitude. The spectral data of van Rhijn and Schwassmann,[7] Malmquist,[10] van de Kamp and Vyssotsky,[8] Lindblad,[13] and Petersson[14] make possible the computation of density gradients perpendicular to the galactic plane. Van Rhijn and Schwassmann have not only computed the density gradients from their own material, but they have also published gradients predicted on the basis of Oort's dynamical study. We should finally mention an investigation by Greenstein[15] in which approximate mean gradients have been derived from general starcounts.

The gradients derived from these various sources are shown graphically in FIGURE 4. The values plotted in this figure represent the logarithms of the numbers of stars per cubic parsec in the interval $M - ½$ to $M + ½$ at the height z, when the corresponding logarithm at $z = 0$ is taken equal to 0.00. For comparison we have also entered the gradients derived later on in this paper from our adopted starcounts and mean parallaxes.

For the absolutely bright stars ($M = -2$, 0 and $+2$) the gradients from starcounts are generally steeper than those derived by van Rhijn and Schwassmann. For these same absolute magnitudes the starcount gradients agree well with those derived here from Malmquist's spectral data (see page 232). For the fainter absolute magnitudes the agreement is generally satisfactory. The most disturbing divergence is that for $M = +8$, where the spectral data indicate a steep gradient within 100 parsecs above the plane. The resolution of general starcounts is too small to check a gradient for such faint stars near the sun, but TABLE 9 indicates that the observed star numbers cannot be accounted for unless we assume that this rate of decrease does not persist very far beyond 100 parsecs. It will be necessary to determine the distribution of color indices in the galactic polar cap between $m = 14$ and $m = 19$, in order to obtain the gradient of star density for $M = +8$ with certainty.

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[13] Upsala Medd. No 14. 1926.
[14] Upsala Medd. No. 29. 1927.
[15] ApJ 87: 577. 1938.

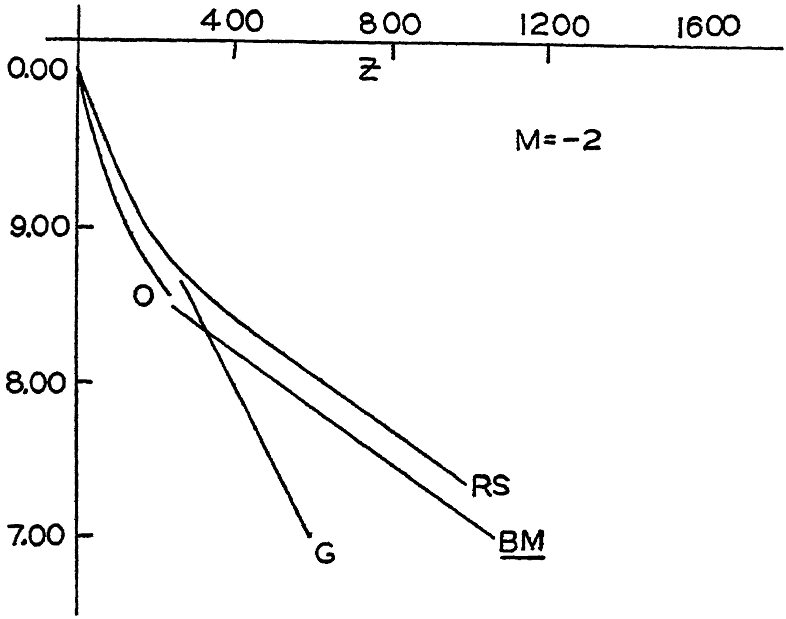

FIGURE 4A.

The Variations in the Stellar Distribution Over the Galactic Polar Cap

Before we proceed with the analysis of our data on the distribution of the stars at the galactic pole we should first investigate the possibility of there being any indications of pronounced irregularities over the galactic polar caps. Since we are primarily interested in large scale variations it will be sufficient to investigate how closely the observed average starcounts and mean parallaxes at latitudes near 40° agree with those predicted on the assumption that over the polar cap the surfaces of equal star density are parallel to the galactic plane.

The comparison would be straightforward if it were not for the possible effects of variations in the galactic absorption over the polar caps. The "half thickness" of the galactic absorbing layer is generally estimated to amount to $0^m.25$. It is, however, quite uncertain whether the galactic poles themselves are affected by these small absorption effects and we have therefore felt justified in omitting them from consideration for $b = \pm 40°$ to $b = \pm 90°$.[16] We may point out that the difference in total galactic absorption at $b = \pm 90°$ and at $b = \pm 45°$ is of the order of $0^m.10$.

[16] Compare Stebbins, Huffer, & Whitford, Publ. A. A. S. 10: 28. 1940.

There are, as we have already seen, definite indications of the variation of the luminosity function with height above the galactic plane. Our assumption of distribution in plane-parallel layers implies therefore that this plane-parallelism holds at various heights for each interval of absolute magnitude.

We define $\varphi(M, z)\, dM$ as the number of stars per cubic parsec with absolute photographic magnitudes between M and $M + dM$ at a height z above the galactic plane. The formulae which represent the starcounts and mean parallaxes at the galactic pole are then:

$$A_{90}(m) = \omega \int_0^\infty dz \cdot z^2 \cdot \varphi(M, z) \tag{1}$$

$$\pi_{90}(m) = \frac{\omega}{A_{90}(m)} \int_0^\infty dz \cdot z \cdot \varphi(M, z) \tag{2}$$

where $M = m + 5 - 5 \log z$.

The corresponding formulae for latitude b, derived on the assumption of plane-parallelism and no absorption, are:

$$A_b(m_b) = \frac{\omega}{\sin^3 b} \int_0^\infty dz \cdot z^2 \cdot \varphi(M, z) \tag{3}$$

$$\pi_b(m_b) = \frac{\omega}{\sin^2 b\, A_b(m_b)} \int_0^\infty dz \cdot z \cdot \varphi(M, z) \tag{4}$$

where $M = m_b + 5 - 5 \log z + 5 \log \sin b$.

If we define

$$m_{90} = m_b + 5 \log \sin b \tag{5}$$

we can re-write these formulae in the more convenient form:

$$A_b(m_b) = \frac{1}{\sin^3 b} A_{90}(m_{90}) \tag{6}$$

$$\pi_b(m_b) = \sin b\ \pi_{90}(m_{90}) \tag{7}$$

Formulae (6) and (7) render it possible to check directly from the starcounts and mean parallaxes the approximate plane-parallelism of the surfaces of equal star density over the part of our galaxy included in the galactic polar cap.

Using the adopted values of $A_{90}(m)$ TABLE 1, we have computed with the aid of (6) the predicted values for $b = 50°$ and $b = 40°$. The comparison between these quantities and the observed averages according to van Rhijn[17] is shown in TABLE 4. For the mean parallaxes

[17] Groningen Publ. No. 43. 1929. TABLE 6.

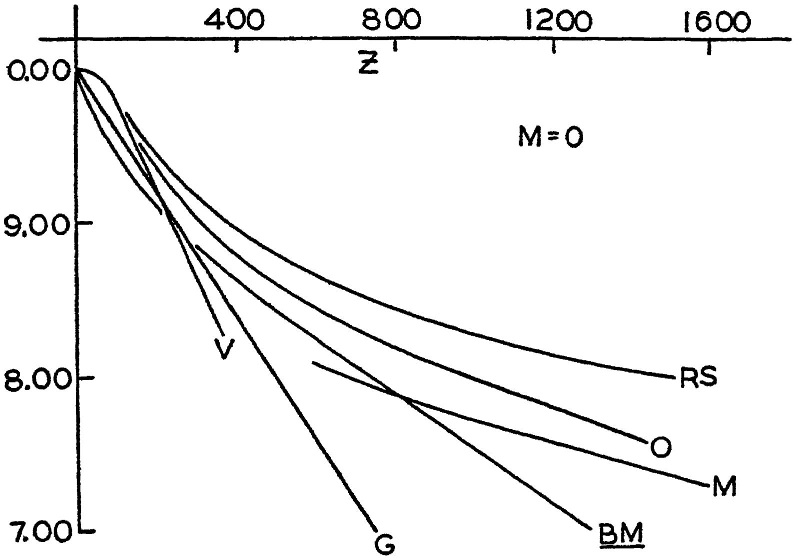

FIGURE 4B.

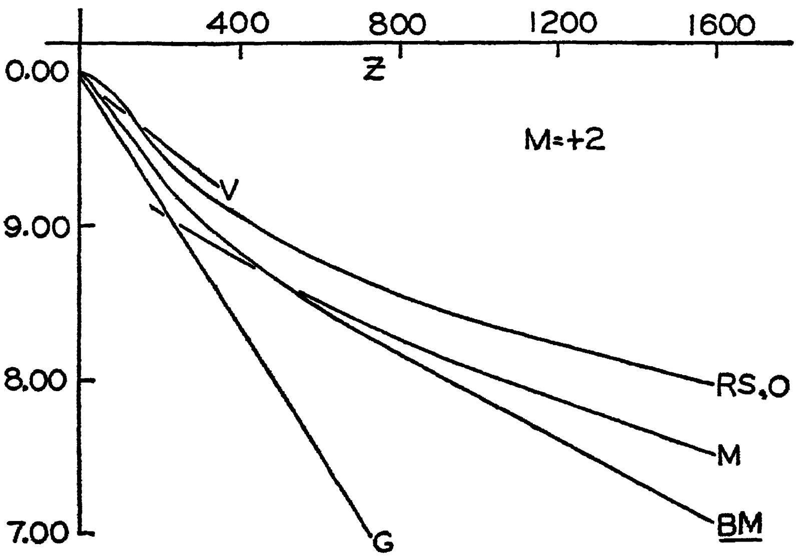

FIGURE 4C.

we have adopted Oort's[18] values for $b = 74°$ and predicted from these the mean parallaxes for $b = 51°$. The comparison between the observed and predicted mean parallaxes is shown in TABLE 5.

TABLE 4

m_b	$\log A_{50}$ (m_{50}) predicted	observed	$\log A_{40}$ (m_{40}) predicted	observed
6.0	8.75	8.72	8.81	8.76
7.0	9.18	9.15	9.25	9.20
8.0	9.61	9.58	9.68	9.64
9.0	0.05	9.99	0.11	0 05
10.0	0.46	0.38	0.54	0.46
11.0	0.80	0.76	0.89	0.85
12.0	1.10	1.08	1.21	1.22
13.0	1.43	1.42	1.54	1.54
14.0	1.73	1.73	1.84	1.88
15.0	2.00	2.03	2.13	2.18
16.0	2.27	2.30	2.39	2.46
17.0	2.51	2.52	2.64	2.69
18.0	2.75	2.76	2.89	2.90

TABLE 5

m_{51}	π_{51} (m_{51}) predicted	observed
12.0	″.0041	″.0043
13.0	.0027	.0028
14.0	.0020	.0022
14.8	.0017	.0014

We conclude from the close agreement in these two tables that a careful analysis of the distribution data at the galactic pole will yield information about the function $\varphi(M, z)$ which should be fully applicable to the entire polar cap between galactic latitudes 40° and 90°.

The Representation of Starcounts and Mean Parallaxes

From the general luminosity function in the galactic plane, as given in TABLE 3, and the density gradients for various absolute magnitudes, as derived by van Rhijn and Schwassmann,[7] we can readily predict values of $\log A(m)$ at the galactic pole. TABLE 6

[18] BAN 290. 1936. TABLE 10.

TABLE 6

$z \backslash m$	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
10	.000	.001	.001	.00	.00											
16	.001	.001	.002	.00	.00	.00										
25	.002	.004	.005	.01	.01	.01	0.0	0.0	0.0							
40	.006	.007	.015	.02	.03	.04	0.0	0.1	0.1	0						
63	.006	.018	.023	.05	.08	.12	0.2	0.2	0.2	0	0	0	0	0	0	M
100	.004	.019	.057	.08	.19	.27	0.4	0.6	0 7	1	1	1	1	1	2	
158	.001	.009	.047	.15	.21	.49	0.7	1.3	1 7	2	3	3	4	4	5	+13
251	.000	.003	.019	.10	.32	.48	1.2	1.9	3.3	5	7	8	10	12	13	
400	.000	.001	.005	.04	.19	.63	0.9	2.3	4 0	8	12	18	24	29	34	+11
630		.000	.002	.01	.07	.36	1.2	1.7	4.4	8	16	27	43	65	85	
1000			.000	.00	.01	.12	.7	2.1	3 3	8	16	34	63	100	151	+9
1580					.00	.04	.2	1 7	5.6	11	26	54	96	158	251	
2500						.01	.1	.9	5.2	28	44	118	214	478	794	
								−1		+1	+3		+5			+7
$A(m)$:	.020	.063	.176	.46	1.11	2.57	5.6	12.8	28.5	71	125	263	455	847	1335	
observed:		.045	.130	.33	.89	2 00	4.2	9.0	18	33	63	119	206	375		

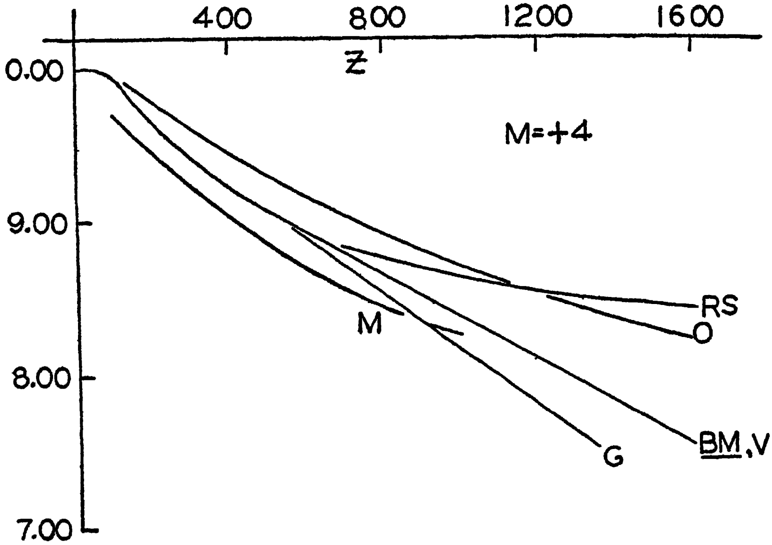

FIGURE 4D.

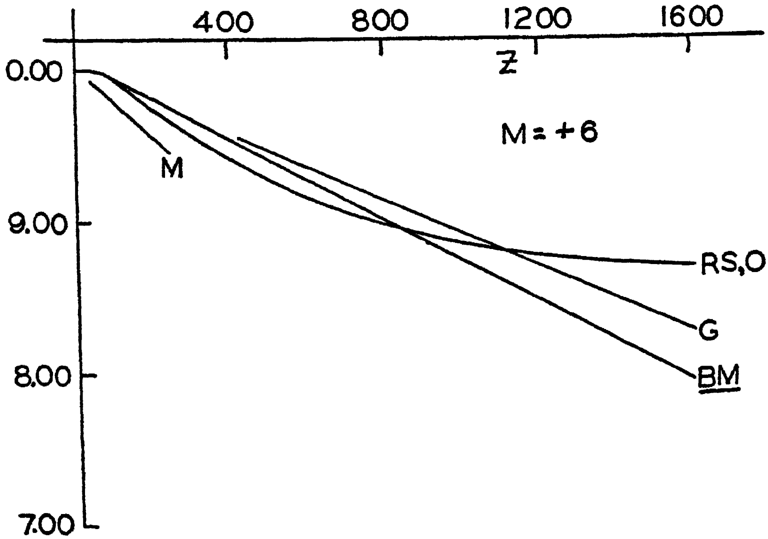

FIGURE 4E.

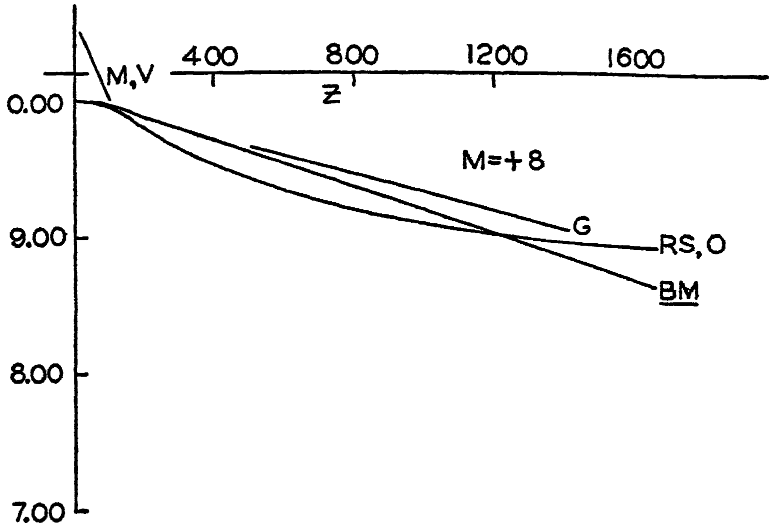

FIGURE 4F.

shows that the agreement between observed and predicted values is not satisfactory.

We have decided to retain the luminosity function in the plane as given in TABLE 3, but to adjust the density gradients so as to fit both the starcounts and the mean parallaxes. These density gradients have been drawn in FIGURE 4.

The comparison between the observed and computed values of the starcounts and of the mean parallaxes is shown from TABLES 7 and 8

TABLE 7

m	$A_{90}(m)$ computed	$A_{90}(m)$ observed
6.0	.045	.045
7.0	.130	.130
8.0	.36	.33
9.0	.91	.89
10 0	2.08	2.00
11.0	4.3	4.2
12.0	9.4	9.0
13.0	19.3	18.
14.0	34	33
15.0	64	63
16.0	117	119
17.0	217	206
18.0	375	375

TABLE 8

m	$\pi_{90}(m)$ computed	$\pi_{90}(m)$ observed
9.0	″.0080	″.0090
10.0	.0063	.0063
11.0	.0049	.0048
12.0	.0042	.0036
13.0	.0034	.0028
14.0	.0030	.0022

to be quite satisfactory. The (m, log π) table in TABLE 9 gives the distribution in absolute magnitude (or distance) for the stars of each successive apparent magnitude. It is consistent with the accepted luminosity function in the galactic plane and the observed starcounts and mean parallaxes at the galactic pole.

The Frequency of Spectral Types

The basic data on the distribution of spectral types at the north galactic pole are given in FIGURE 2. In the analysis of this material we have used the values of the mean absolute photographic magnitudes listed in TABLE 10. The dispersion about the mean was taken to be $\pm 1^m.0$ for all spectral types. The means, as taken from TABLE 6 of "The Distribution of the Stars in Space", (these means are based on the data of van Rhijn and Schwassmann[7]) were corrected for the effect of volume by Malmquist's formula.[19]

A separate table was then prepared for each apparent magnitude $m = 9$, 10, 11, 12 and 13, in which the distribution in absolute magnitude of the observed stars of each spectral class was tabulated. By the addition of the numbers for the separate spectral types the distributions in absolute magnitude—and hence in distance—for the stars of $m =$ 9, 10, 11, 12 and 13 were then derived. These distribution data were checked with the aid of color indices determined by Malmquist[4] for $m = 12$ and 13. The agreement between the two sets of data was found to be quite satisfactory. Malmquist's colors beyond $m = 13$ are incomplete and were therefore not used in our analysis.

For comparison with TABLE 9 we reproduce in TABLE 11 the part of the (m, log π) table derived now entirely from the spectral data. The spread in distance from the spectral data is noticeably larger, but

[19] Lund Medd. Series II. No. 22. 1920.

TABLE 9

$z \diagdown m_{90}$	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
10	.000	.001	.001	.00												
16	.001	.001	.002	.00	.00	.00										
25	.002	.004	.005	.01	.01	.01	.0	.0	.0							
40	.004	.006	.015	.02	.03	.04	.0	.1	.1	0						
63	.004	.015	.022	.06	.09	.12	.2	.2	.2	0	0	0	0	0	0	
100	.002	.011	.042	.08	.21	.32	.4	.6	.8	1	1	1	1	2	2	
158	.000	.005	.030	.11	.22	.59	.9	1.4	2.0	3	3	4	5	6	6	M
251		.001	.010	.06	.22	.41	1.3	2.4	4.3	6	8	12	15	21	23	+13
400		.001	.002	.02	.10	.38	.7	2.6	5.0	10	18	25	39	60	81	
630		.000	.001	.00	.03	.18	.6	1.2	4.9	8	21	42	65	108	229	+11
1000			.000	.00	.00	.03	.2	.8	1.6	5	10	26	74	124	330	
1580						.00	.0	.1	.4	1	3	7	18	52	120	+9
2500							.0	.0	.0	0	0	0	0	2	4	
								−1		+1		+3		+5		+7
$A_{90}(m_{90})$:	.013	.045	.130	36	.91	2.08	4.3	9.4	19.3	34	64	117	217	375	795	

TABLE 10

Spectrum	mean absolute photographic magnitude	after correction for volume
A	$+2^m.0$	$+2^m.0$
F0	2 .5	2 .5
F2	3 .0	2 .5
F5	4 .0	3 .0
F8	5 .0	4 .0
dG	6 .0	5 .0
gG	2 .0	2 .0
dK	9 .0	8 .0
gK	2 .0	2 .0

TABLE 11

	From TABLE 9					Malmquist's Data				
z \ m	9	10	11	12	13	9	10	11	12	13
10							.01	0.0		
16	0	0				0	.04	0.0	0.0	
25	.01	.01	.0	.0	.0	.01	.05	0.0	0.1	0.0
40	.03	.04	.0	.1	.1	.04	.06	0.1	0.2	0.1
63	.09	.12	.2	.2	.2	.09	.13	0.1	0.5	0.6
100	.21	.32	.4	.6	.8	.14	.26	0.4	0.5	1.1
158	.22	.59	.9	1.4	2.0	.20	.35	0.7	1.1	1.3
251	.22	.41	1.3	2.4	4.3	.20	.44	0.8	1.9	2.8
400	.10	.38	.7	2.6	5.0	.11	.44	0.9	1.9	4.7
630	.03	.18	.6	1.2	4.9	.02	.23	0.8	1.6	4.0
1000	0	.03	.2	.8	1.6	.00	.05	0.4	1.2	2.3
1580		0	.0	.1	.4		.00	0.1	0.6	1.4
2500				.0	.0			0.0	0.1	0.5
A_{90} (m_{90}):	.91	2.08	4.3	9.4	19.3	.81	2.06	4.3	9.7	18.8

the agreement is on the whole quite satisfactory. In TABLE 12 we present a comparison between the mean parallaxes as computed from TABLE 11 and the observed values. The differences are larger than for TABLE 9, but the absence of a systematic trend is satisfactory. In the present state of our knowledge about stellar distribution in the polar caps it is difficult to choose between the left and right hand parts of TABLE 11.

TABLE 12

m	$\pi_{90}(m)$	
	From Table 11	Observed
9.0	″.0083	″.0090
10.0	.0082	.0063
11.0	.0046	.0048
12.0	.0048	.0036
13.0	.0034	.0028

The Adopted (m, log π) Table

We have now derived two (m, log π) tables which represent the stellar distribution at the north galactic pole. TABLE 9 takes into account all available data on starcounts and mean parallaxes, whereas TABLE 11 has been computed from Malmquist's spectral data. The second table does not represent as large an interval in apparent magnitude as the first one, and, though for the interval in common the resolving power of the spectral data is larger than that for the general starcounts, we should take into account that Malmquist's published results are only preliminary. While certain differences between the two tables are present, the agreement is on the whole satisfactory. The differences are not large enough to invalidate the use of either table as a basis for the analysis in intermediate latitudes. We have decided to use TABLE 9 as our basic (m, log π) table. As far as we can tell there are no pronounced systematic differences in the stellar distributions for the north and south galactic polar caps. Because of the lack of data at the south galactic pole we shall assume that TABLE 9 may be used indiscriminately for regions north or south of the galactic plane.

It is of interest to examine the entries in TABLE 9 more closely. The numbers in each horizontal row represent the distribution in absolute magnitude for a particular distance shell. After applying a constant correction for volume we obtain directly the luminosity function at each height, z. FIGURE 5 shows the variation with z of the general luminosity function according to TABLE 9.

The lines of equal absolute magnitude run diagonally through the (m, log π) table. The numbers along any diagonal yield, again after the application of a correction for volume, the density gradients for a particular absolute magnitude. The gradient curves computed from TABLE 9 have already been reproduced in FIGURE 4.

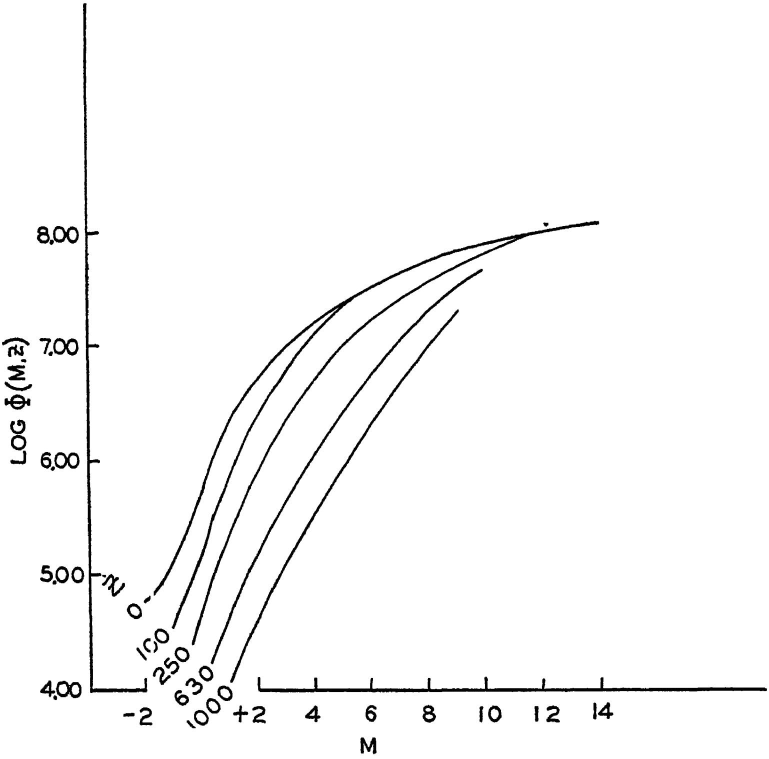

FIGURE 5.

The vertical columns show the distribution in distance for the stars of different apparent magnitudes. The frequency distribution in distance has been represented graphically for some apparent magnitudes in FIGURE 6.

It may finally be of interest to list the mean parallaxes computed from TABLE 9 for $m = 15$ to 18. The results in TABLE 13 show that there is some hope that we should be able to check the predicted values if accurate absolute proper motions can be derived for 15th to 18th magnitude stars.

TABLE 13

m	$\pi_{90}(m)$, predicted
15	″.0024
16	.0021
17	.0018
18	.0017

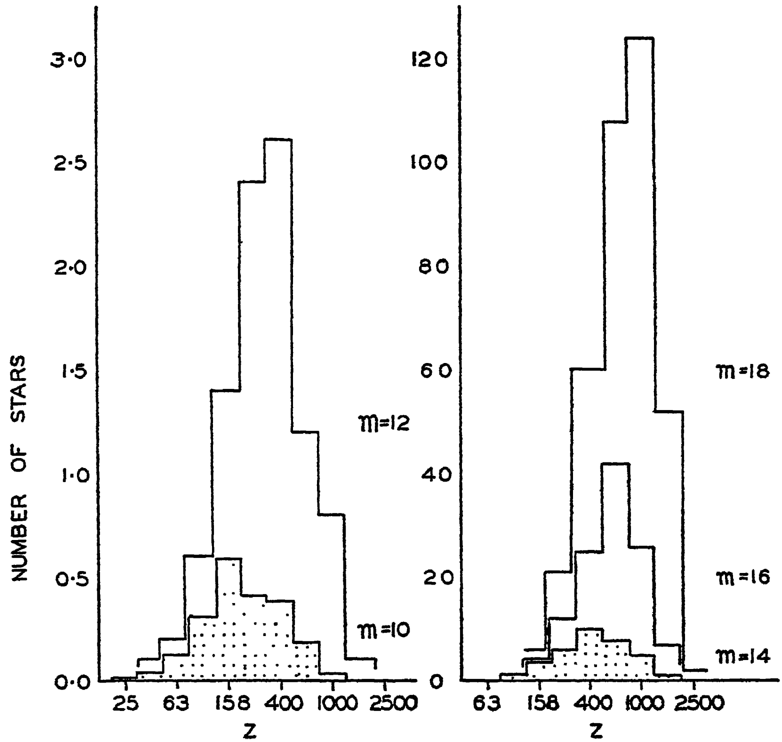

FIGURE 6.

THE ZONE OF INTERMEDIATE LATITUDES

The Modified Oort-Vashakidse Method

In 1938 an extensive paper on the stellar distribution in intermediate latitudes was published by Oort.[20] For the analysis of starcounts in regions for which the total obscuration is known Oort made use of a simple geometric method that was developed independently by Oort[21] and by Vashakidse.[22] It has been shown already in the preceding section that in the absence of absorption and for the case that the surfaces of equal star density are planes parallel to the galactic plane, the relation between the starcounts at the galactic pole and at latitude b is given by formulae (5) and (6). If absorption of an amount Δa

[20] BAN No. 308. 1938.
[21] Ann. Astrophys. 1: 71. 1938.
[22] Bull. Abastumani Obs. No. 1. 87. 1937.

affects equally the light of all stars of apparent magnitude m_b, formula (6) will still hold, but instead of (5) we should write

$$m_{90} = m_b + 5 \log \sin b - \Delta a. \tag{8}$$

Oort's procedure for the study of deviations from the simple plane-parallel distribution was the following: For $m_{90} = 10$, 12, 14, 16 and 17 the corresponding values of m_b were computed with the aid of (8). The predicted values of $A_b(m_b)$ were then found from (6) and the quantities $\Delta \log A(m)$ were found, which represent the differences between the observed values of $\log A_b(m_b)$ and the expected values from (6). These differences were taken to be a measure for the excess or deficiency in the star density at a height, z_0, corresponding to the logarithmic average mean distance from the galactic plane for the stars of apparent magnitude m_{90} at the galactic poles.

Oort's results are provisional and admittedly uncertain partly because it is at present very difficult to decide for the layers close to the galactic plane whether or not the estimated absorption Δa affects all stars of apparent magnitude m_b. There are also the uncertainties arising from the errors in the estimated total absorption. At this point we are, however, more concerned with the method as such than with the observations.

If we grant the observations, a positive $\Delta \log A(m)$ does certainly indicate, somewhere along the line of sight, an excess of star density over that computed from the hypothesis of plane-parallelism of the surfaces of equal star density. Some simple constructed examples show, however, that because of the large spread in the general luminosity function it is unsafe to assume that the excess occurs at the height z_0 corresponding to m_{90}. A small percentage excess at a distance well beyond z_0 may result in a positive value for $\Delta \log A(m)$ even though the star density at z_0 for that particular latitude does not deviate from that for plane-parallel layers. The interpretation of Oort's quantities $\Delta \log A(m)$ is therefore quite difficult.

It is possible on the other hand to modify the Oort-Vashakidse method so as to take account of the large spread in absolute magnitude for the stars under consideration. We shall do so by making use of the basic $(m, \log \pi)$ table in TABLE 9, which represents the distribution over the various distance-shells of the stars at the galactic poles.

Let $\varphi(M, z)\, dM$ be defined as in the first section as the number of stars per cubic parsec with absolute magnitudes M to $M + dM$ at a

height z above the galactic plane, for the direction of the galactic poles. Let the corresponding number for a field at longitude l, latitude b, be called $D(M, z)\ \varphi(M, z)$. We can then write for the star numbers in the field at (l, b):

$$A_b(m_b) = \omega \int_0^\infty dr \cdot r^2 \cdot D(M, z)\ \varphi(M, z)$$

where $r = \frac{z}{\sin b}$ and $M = m_b + 5 - 5 \log r - \Delta a(r)$, $\Delta a(r)$ being again the total absorption at distance r. After a change of variables this formula reads:

$$A_b(m_b) = \frac{\omega}{\sin^3 b} \int^\infty dz \cdot z^2 \cdot D(M, z)\ \varphi(M, z) \tag{9}$$

with $M = m_b + 5 - 5 \log z + 5 \log \sin b - \Delta a(z)$. (10)

Oort's procedure is essentially to put $D(M, z) = \overline{D}$, a constant. Oort's quantity $\Delta \log A(m)$ is then equal to $\log \overline{D}$.

Since we do not wish to make the assumption that $D(M, z)$ is constant for the range in M and z contributing to a given apparent magnitude we reduce the observed starcounts at latitude b with the aid of the formula:

$$A_{90}(m_{90}) = \sin^3 b \cdot A_b(m_b) \tag{11}$$

where $m_{90} = m_b + 5 \log \sin b$. (12)

Formulae (9) and (10) will then read:

$$A_{90}(m_{90}) = \omega \int_0^\infty dz \cdot z^2 \cdot D(M, z)\ \varphi(M, z) \tag{13}$$

with $M = m_{90} + 5 - 5 \log z - \Delta a\ (z)$. (14)

(13) and (14) suggest the following procedure for the computation of $D(M, z)$:

1. Compute the quantities $A_{90}(m_{90})$ with the aid of (11) and (12).
2. Shift to the right the entries in the horizontal rows of the basic $(m, \log \pi)$ table for the galactic poles (TABLE 9) by amounts corresponding to the magnitude shift Δa for the height $z = r \sin b$.
3. Find by trial and error the quantities $D(M, z)$ by which the entries in the modified $(m, \log \pi)$ table should be multiplied if we wish to represent the reduced values $A_{90}(m_{90})$ computed from (11) and (12).

The procedure just described is quick and rigorous and yields all the information contained in the general starcounts. In practice we

shall have to make certain assumptions about $D(M, z)$. If the observed range in apparent magnitude is small we can hardly do more than assume that $D(M, z) = D(z)$, which is independent of the absolute magnitude. If the observed range in apparent magnitudes is large we may hope to find evidence for differences between $D(M, z)$ at a given z for intrinsically bright and intrinsically faint stars. In a first attempt it is, however, advisable to assume that $D(M, z)$ is independent of the absolute magnitude.

The quantities $D(M, z)$ have little in common with the star densities as they have usually been defined. The conspicuous and well-established general thinning-out of the stars perpendicular to the galactic plane is taken into account in our basic $(m, \log \pi)$ table for the polar caps (TABLE 9). The quantities $D(M, z)$ measure strictly the factor by which the true star densities for a particular line of sight differ from those found for the direction of the galactic poles. For the ideal case of plane-parallel surfaces of equal star densities all $D(M, z)$'s should be equal to 1.0.*

The suggested procedure is well adapted to numerical computation because one single $(m, \log \pi)$ table serves for the analysis of the reduced counts in all latitudes. As an illustration of the procedure we shall close with the detailed analysis for Selected Area 43.

The adopted starcounts for successive values of m_b are listed in the first two columns of TABLE 14. Since for the latitude of SA 43

$$\log \sin b = -0.553$$

we have from (11) and (12)

TABLE 14

m_b	$\log A_b(m_b)$	m_{90}	$\log A_{90}(m_{90})$
7.00	9.41	4.24	7.75
8.00	0.09	5.24	8.43
9.00	0.55	6.24	8.89
10.00	0.98	7.24	9.32
11.00	1.28	8 24	9.62
12.00	1.62	9.24	9.96
13.00	1.97	10.24	0.31
14.00	2.32	11.24	0.66
15.00	2.64	12.24	0.98
16.00	2.89	13.24	1.23
17.00	3.14	14.24	1.48
18.00	3.49	15.24	1.83

* The introduction of star densities of this sort has been suggested by Dr. F. D. Miller and Miss Risley.

$$\log A_{90}(m_{90}) = \log A_b(m_b) - 1.66$$
$$m_{90} = m_b - 2.76.$$

The corresponding values of m_{90} and $\log A_{90}(m_{90})$ are listed in the third and fourth columns of TABLE 14. By interpolation we can then obtain the values of $\log A_{90}(m_{90})$ for integral values of m_{90}.

Our next step is to compute the predicted values of $A_{90}(m_{90})$ on various assumptions about the magnitude and distribution of the absorption. Three possibilities, listed in TABLE 15, were considered.

TABLE 15

z	absorption $0^m.0$	absorption $0^m.5$	absorption $1^m.0$
≤ 40	0.0	0.0	0.0
63	.0	.0	.1
100	.0	.1	.3
158	.0	.3	.5
≥ 250	.0	5	1 0

The necessary adjustments were made in our basic $(m, \log \pi)$ table (TABLE 9) and the predicted values of $A_{90}(m_{90})$ are given in the third, fourth and fifth rows of TABLE 16.

TABLE 16

m_{90}	6	7	8	9	10	11	12	13	14	15
observed $A_{90}(m_{90})$	.061	.162	.37	.73	1.67	4.1	7.7	15.4	27.3	42.5
predicted, no abs.	.045	.130	.36	.91	2.08	4.3	9.4	19.3	34.	64
predicted, $0^m.5$ abs.	.039	.103	.26	.65	1.49	3.0	6.6	14.3	25	48
predicted, $1^m.0$ abs.	.034	.086	.21	.51	1.16	2.3	4.9	9.8	19	34

The resulting values for $D(z)$ are listed in TABLE 17. We did not find it necessary to include a variation of $D(M, z)$ with the absolute magnitude.

The most probable value for the total absorption is $\Delta a = 0.5$ and we conclude therefore that for the direction of SA 43 there exists a definite excess in star density over that computed on the assumption of plane parallel layers. For corresponding values of z the star density for the direction of SA 43 is in excess of that for the direction of the galactic pole by 50% at $z = 100$, by 20% at $z = 160$ whereas there is no suggestion of an excess or deficiency for $z = 200$

TABLE 17

z	$\Delta a = 0.0$	$\Delta a = 0.5$	$\Delta a = 1.0$
$\geq$ 25	2.0	2.0	2.0
40	1.5	1.8	1.8
63	1.2	1.5	1 8
100	1.0	1.5	1.8
158	1.0	1.2	1.5
251	0.8	1.0	1.5
400	0.8	1.0	1.2
630	0.5	1.0	1.2
1000	0.5?	1.0?	1 0?

to 600. An inspection of the final (m, log π) table shows that at latitude 16°, we cannot obtain from our starcounts to $m_b = 18$ information on the run of the $D(z)$'s beyond $z = 600$ parsecs.

The Densities for some Selected Regions

Our method of analysis is here applied to the observations in those regions in the zone $b = \pm 10°$ to $\pm 30°$ for which starcounts and data on the interstellar absorption are available. Because of the uncertainties in the absorptions, we have limited our investigation to centers for which there seems good reason to suppose that the total absorption is small, not in excess of $\Delta a = 1^m.0$. We shall proceed to treat separately each section in galactic longitude for which sufficient data are available. All galactic latitudes and longitudes will be referred to the Harvard Pole at $\alpha = 12^h\ 40^m$, $\delta = +28°$.

FIGURES 7 to 14 represent sections of the galaxy cut by planes perpendicular to the galactic plane, passing through the sun, and directed towards the various longitudes. In the small diagrams at

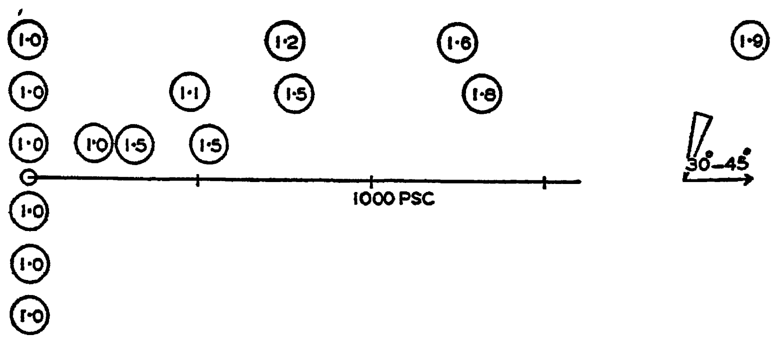

FIGURE 7.

the right of each figure, the arrow represents the direction towards the galactic center, and the sector shows the relative position of the longitudes under consideration.

$l = 30°$ to $45°$

Miller and Hynek's[23] starcounts in Cygnus provide data for $l = 30°$ to $40°$ at $b = +10°$. Their counts cover the range between $m = 8.0$ and $m = 18.0$. From their discussion of the available color and galaxy data, we find that $\Delta a = 1^m.0$. This absorption was assumed to be distributed uniformly between $z = 0$ and $z = 350$ parsecs.

SA 38 and SA 37 fall in the same longitudes at latitudes $b = +18°$ and $b = +28°$. Data on the distribution of faint galaxies collected at Mount Wilson[24] and at Harvard[25] show that the most

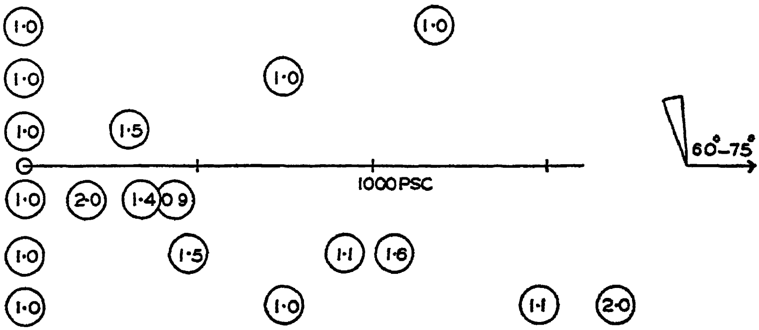

FIGURE 8.

probable values for the absorption are $\Delta a = 0.4$ for SA 37 and $\Delta a = 0.0$ for SA 38. In order to get the full effect of the small absorption we have assumed that it takes place within $z = 100$ parsecs.

The resulting values of $D(z)$ are shown in FIGURE 7. We conclude that the presence of an excess of 50% over the densities at the pole is established for $z = 100$ to 300 parsecs at $r = 700$ parsecs.

$l = 60°$ to $75°$

Unpublished starcounts by Miss Risley are available for the smooth zone at $b = -15°$. A discussion of the color and galaxy data shows that the total absorption is of the order of $\Delta a = 1^m.0$ to $1^m.5$ for the region under investigation. Miss Risley's starcounts have been sup-

[23] Contr. Perkins Obs. No. 13. 1939.
[24] ApJ 79: 8. 1934; Mt. Wilson Contr. No. 485.
[25] Proc. Nat. Acad. Sci. 26: 554. 1940; H.R. 208.

plemented by those for SA 42, at $b = -13°$, where the absorption is about the same. Further south of the galactic belt we find, at $b = -28°$, SA 67 for which $\Delta a = 0.6$, whereas to the north we find in a relatively unobscured field, for which galaxy data give $\Delta a = 0.4$, SA 17 at $b = +19°$. We note from FIGURE 8 that the average value of $D(z)$ at $z = \pm 200$ parsecs and $r = 600$ parsecs equals 1.3.

$l = 75°$ to $95°$

Published starcounts by Baker,[26] together with the data for SA 43, and some unpublished material by MacRae, yield accurate counts for a center near $l = 80°$, $b = -17°$. Baker has shown that colors and galaxy data give $\Delta a = 0.5$ for the most probable value of the

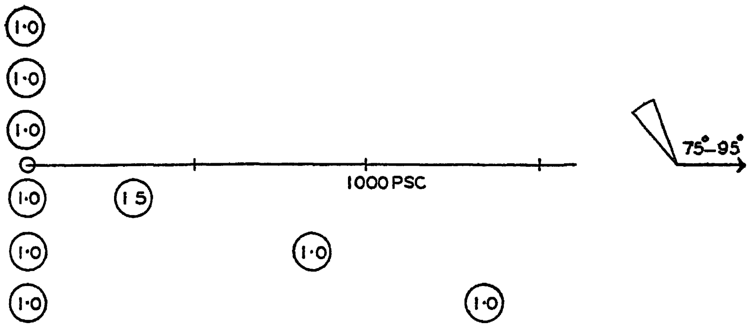

FIGURE 9.

total absorption in this direction. The graphical representation in FIGURE 9 shows that the excess is not unlike that for the preceding section.

$l = 88°$ to $118°$

In addition to some unpublished starcounts by Evans for the zone at $b = -13°.5$, we have south of the plane SA 20 and 21 at $b = -17°$, and SA 46 at $b = -27°$, and north of the plane SA 1 at $b = +28°$. Color and galaxy data show that $\Delta a = 1.0$ at $b = -13°.5$. We have found from galaxy data $\Delta a = 0.6$ for SA 20 and 21, $\Delta a = 0.2$ for SA 46 and $\Delta a = 0.8$ for SA 1. The latter value agrees with the observed color excesses at the north celestial pole.

FIGURE 10 shows that for this section there exist probably some small excesses, but it is unlikely that the average value of $D(z)$ will exceed $D(z) = 1.5$ for $z = 0$ to ± 200 parsecs.

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[26] HC 424. 1939.

$l = 120°$ to $130°$

McCuskey[27] has counted the stars in the region of the great dark nebula in Taurus. In the course of his investigation he found that the section $l = 120°$ to $130°$ in the latitude zone $b = -25°$ to $-30°$ was essentially unobscured. North of the galactic plane Harvard and Mount Wilson counts of galaxies suggest that $\Delta a = 0.4$ for SA 11, which is found at $l = 123°$, $b = +27°$. FIGURE 11 shows the densities for this section. The excess north of the galactic plane is small, and the deficiency south of the plane seems well established.

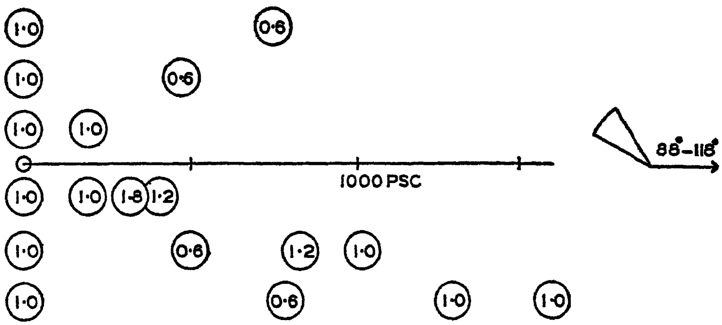

FIGURE 10.

$l = 135°$ to $215°$

In this particular section we have depended entirely on starcounts for Selected Areas for which the total absorptions can be estimated reasonably well from galaxy counts made at Mount Wilson and Harvard. The positions of these Selected Areas, the estimated total absorptions, and the values of $D(z)$ at $z = 100$ and $z = 250$ parsecs are listed in TABLE 18. The densities are plotted all together in FIGURE 12.

The computed excesses and deficiencies are without exception small and we feel justified in concluding that, at least north of the galactic circle, there is for this particular region of galactic longitude no indication of pronounced deviations from plane-parallelism in the layers of equal star density.

$l = 190°$ to $280°$

Starcounts by Lindsay and Bok[5] and some unpublished counts by Lindsay provide the basic data on the stellar distribution in this sec-

[27] ApJ 88: 209. 1938.

tion. North of the galactic circle three areas were chosen for which the absorption is small according to unpublished Harvard counts of galaxies. The positions of the centers, the absorption and the estimated values of $D(z)$ at $z = 100$ and 250 parsecs are listed in TABLE 18.

One of the most interesting regions in the southern hemisphere is that between $l = 190°$ and $250°$ and $b = -20°$ to $-30°$. The star-

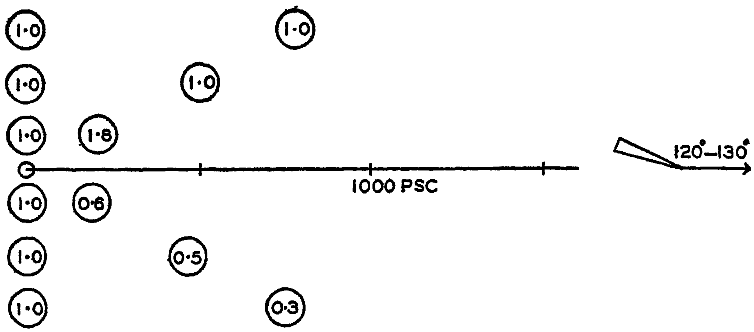

FIGURE 11.

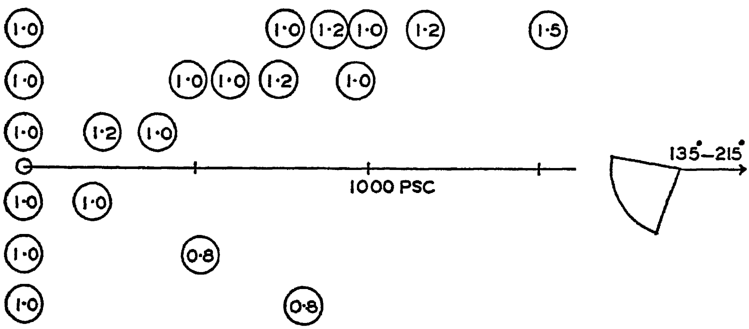

FIGURE 12.

counts in this section show little evidence of fluctuations in this zone, which is rich in galaxies. Harvard galaxy counts are available in unpublished form for nineteen different centers in this zone. The average value of Δa proves to be equal to $\Delta a = -0.4$, which is indicative of an excess of galaxies. Even if we consider that Shapley's metagalactic density gradient[28] may reach down to these latitudes, we still have every indication that the average absorption in this zone is negligible. The analysis of the available starcounts shows

[28] Proc. Nat. Acad. Sci. 24: 282. 1938; H. R. 150.

that $D(100) = D(250) = 0.90$. The reality of a slight deficiency appears to be well established. The results are reproduced graphically in FIGURE 13.

$l = 300°$ $b = -11°.5$

Bok and Lindsay[29] have analyzed the stellar distribution for Shapley's southern galactic window. If we assume $\Delta a = 0.4$, the star-

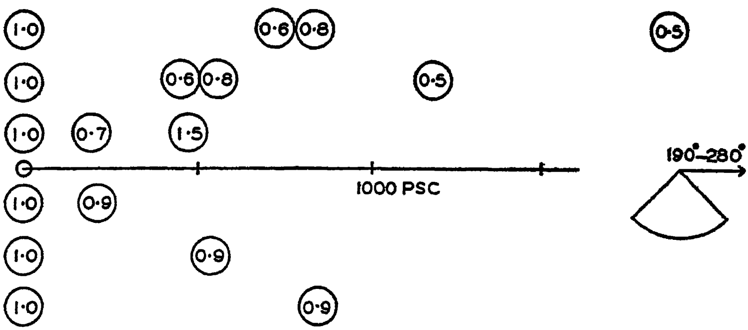

FIGURE 13.

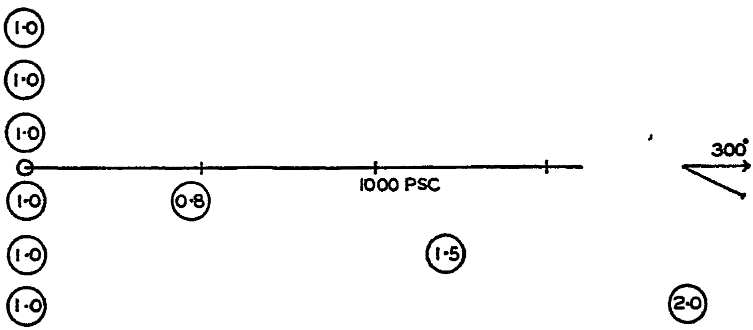

FIGURE 14.

counts show that $D(100) = 0.8$ and $D(250) = 1.5$. This result is shown graphically in FIGURE 14.

Comparison with Oort's Results

The results of the last section are directly comparable with those of Oort.[20] For a given area there is generally fairly close agreement between our values of $D(z)$ and Oort's corresponding values of $\Delta \log A(m)$. We find, however, from our analysis that from star-

[29] Proc. Nat. Acad. Sci. 24: 4. 1938; H. R. 144.

TABLE 18

CALCULATED VALUES OF $D(z)$

Region	Miller	SA 38	SA 37	Risley I	Risley II	SA 42 I	SA 42 II	SA 67	SA 17	SA 43 etc.	Evans	SA 21	SA 20	SA 46	SA 1
l	35	42	39	65–75		70		65	59	80	88–118	99	89	117	91
b	+10	+18	+28	−15		−13		−28	+19	−17	−14	−17	−17	−27	+28
Δa	1.0	0.4	0.0	1.0	1.5	1.0	1.5	0.6	0.4	0.5	1.0	0.6	0.6	0.2	0.6
$z =$ 40	1.4	1.4	1.0	1.6	2.0	2.0	2.0	2.0	1.5	1.8	1.5	3.0	1.5	1.5	1.0
63	1.5	1.5	1.0	1.6	1.8	1.5	1.5	2.0	1.5	1.5	1.5	3.0	1.5	1.5	1.0
100	1.5	1.5	1.0	1.3	1.5	0.7	1.0	2.0	1.5	1.5	1.2	2.0	1.5	1.0	1.0
158	1.6	1.5	1.0	1.0	1.3	0.7	1.2	2.0	1.2	1.2	1.0	1.5	1.5	0.8	0.8
251	1.8	1.5	1.1	1.0	1.2	1.6	1.6	1.5	1.0	1.0	1.0	1.2	1.2	0.6	0.6
400	1.9	1.6	1.2	1.0	1.2	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.6
630	2.0	1.6	1.2			2.5	3.0	0.8	1.0	1.0	1.0	1.0	1.0	0.6	1.0

CALCULATED VALUES of D(z) *continued*

Region	McCuskey	SA 11	SA 26	SA 27	SA 51	SA 76	SA 121	SA 99	SA 100	SA 125	l = 190° to 280°				Galactic Window
l	120–130	123	138	141	156	177	184	188	196	214	190–250	205	259	276	300
b	−28	+27	+19	+29	+22	+27	−26	+15	+28	+24	−25	+26	+12	+29	−11.5
Δa	0.0	0.4	0.6	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.0	0.0	0.4	0.0	0.4
$z =$ 40	1.5	2.2	2.2	1.4	1.2	1.0	1.5	1.0	2.0	1.2		0.8	1.5	0.6	0.6
63	1.0	2.0	1.8	1.4	1.0	1.0	1.5	1.0	1.3	1.2	0.9	0.8	1.5	0.6	0.6
100	0.6	1.8	1.5	1.4	0.8	1.0	1.0	1.0	1.3	1.2	0.9	0.8	1.5	0.6	0.8
158	0.6	1.4	1.3	1.0	0.5	1.0	0.8	1.0	1.3	1.2	0.9	0.8	1.0	0.6	1.0
251	0.5	1.0	1.2	0.9	0.8	0.8	0.8	1.0	1.3	1.2	0.9	0.8	0.5	0.6	1.5
400	0.3	1.0	1.2	0.8	1.0	0.8	0.8	1.5	1.3	1.2	0.9	0.8	0.5	0.6	2.0
630	0.1	0.8	1.0	0.8	1.0	0.8	0.8	1.8	1.3	1.2		0.8		0.6	2.5

counts to $m = 18$ or 19 in the zone $b = 0°$ to $\pm 30°$ $D(z)$ can not be reliably determined beyond $z = 800$ parsecs. This is partly because the spread in the general luminosity function is large and partly because the effective mean absolute magnitude grows rapidly fainter as we go to fainter apparent magnitudes.

Our results show that $D(z)$ averages 1.3 to 1.5 for $z = \pm 100$ to ± 300 parsecs in the section $l = 30°$ to $90°$. These excesses persist, but are generally smaller for $l = 90°$ to $135°$, where the first definite deficiencies make their appearance. There is little indication for the presence of either excesses or deficiencies in the section $l = 135°$ to $210°$, but deficiencies are indicated with certainty for $l = 190°$ to $250°$ and slightly beyond. Unfortunately we have so far only data for one region in the section between $l = 300°$ and $l = 30°$. The analysis of the stellar distribution for the direction of the galactic window at $l = 300°$, $b = -11°.5$ shows that $D(z) = 1.0$ for small values of z, but that it becomes as high as 2.0 for $z \geqq 250$ parsecs.

We confirm excesses, somewhat smaller than those of Oort's, in the section $l = 30°$ to $90°$, but find a mixture of small excesses and slight deficiencies for $l = 90°$ to $250°$. It is however significant to note that our values of $D(z)$ only rarely exceed 1.5 and that we have found no trustworthy $D(z)$ larger than 2.0.

It is clearly indicated that the need of material for the section $l = 270°$ to $30°$ is urgent. Work that is now in progress at Harvard and elsewhere should soon provide us with the necessary data. It is further desirable that the analysis from general starcounts be supplemented at several centers by studies of spectra and colors. It is only through a comparative study of the distribution of spectral types in high and intermediate latitudes that we may eventually hope to reach a full understanding of the variations in the stellar distribution near the sun at some distance from the galactic plane.*

* Miss Lois Kiefer and R. H. Baker have supplied us with some unpublished starcounts and color data in Auriga. Dr. Baker has also provided similar material for the Milky Way in Aquila. The Selected Areas were used to extend these starcounts to the fainter magnitudes and additional information on the total absorptions was obtained from the Harvard galaxy counts.

In Auriga the analysis indicates a decrease in the star density to a value about eight-tenths of that in the vicinity of the sun. The eleven centers for which the Illinois starcounts were available give densities which are in excellent agreement. Average values for three latitudes are given in TABLE 18a. In Aquila, on the other hand, there is a clear indication of an excess, running from 1.3 nearby to greater than 2.0 at larger distances. This excess is in evidence in Dr. Baker's counts on both sides of the galactic plane and is of the same order as that found in the galactic window. (Footnote continued on page 250.)

(m, log π) TABLES FOR THE ANALYSIS OF FIELDS IN LOW GALACTIC LATITUDES

The analysis of the density distribution in fields with galactic latitudes between 0° and ± 10° is beyond the scope of the present paper. Our results on the change of luminosity function with height above the galactic plane bear directly however on the problems that confront us if we attempt an analysis in these regions. For fields within ten degrees of the galactic circle the reduction of the counts to the pole and subsequent analysis by the method just outlined is not practicable. We present therefore in TABLES 19 to 24 the (m, log π) tables for even latitudes between 0° and ± 10° in which the variation of the luminosity function with height above the galactic plane has been taken into account.

The entries in these tables are the logarithms of the products of the volume of each element and the appropriate value for $\varphi(M, z)$. The latter quantities have been derived by multiplying the quantities $\varphi(M, o)$ according to TABLE 3 by the relative densities read off from the curves marked "BM" in FIGURES 4a to 4f. For absolute magnitudes $M < -2$, we have used the same density gradients as for $M = -2$. Changes in the luminosity function did not affect the numbers above the jagged lines.

Each table is prepared for the analysis of an area of one square degree of the sky. The quantities z and r are expressed in parsecs; all magnitudes are on the international photographic scale. We have entered in the tables the logarithms of the products of $\varphi(M, z)$ and the volumes in order to facilitate the interpolation for other latitudes. One might instead reduce the observed values of log $A(m)$ to the nearest even degree of latitude.

It is important to realize that the densities obtained from the usual kind of analysis, with the aid of TABLES 19 to 24 are expressed

(Continuation of footnote from page 249)

TABLE 18a

Region	Auriga			Aquila			
l	129	130	130	4	7	20	16
b	+ 12	+ 19	+ 28	+ 26	+ 14	− 15	− 25
Δa	1.0	0 0	0.0	0.5	1.5	1.5	0.5
z = 40	1.1	0.9	1.1	1.0	1.0	1.3	1.2
63	1.0	0.8	1 1	1.0	1.2	1.5	1.3
100	0.9	0.7	1.0	1.1	1.5	1.7	1.4
158	0.9	0.7	1.0	1.2	1.8	1.9	1.4
251	0.9	0.7	0.9	1.3	2.3	2.0	1.6
400	0.9	0.7	0 8	1.5	2.8	2.0	1.6
630	0 9		0.7	2 0	3.5		2.0

in terms of unit density at the same height directly above the sun. Instead of the traditionally small densities at some distance from the galactic plane we shall now find densities that are directly comparable to the quantities $D(M, z)$ and $D(z)$ introduced in this paper. The densities derived from TABLES 19 to 24 fit in directly with the quantities plotted in FIGURES 7 to 14.

TABLES 19 to 24 will of course not take into account the possible changes in the luminosity function directly in the galactic plane. Even though we may feel that we know well the characteristics of the absorption function for a given low-latitude field we should still remember that our analysis may be affected by fluctuations in the general luminosity function. The best partial check on this kind of error can be made from the analysis of the spectral distribution in the area under investigation. From an analysis of the observed numbers of stars of known spectral type we can build up an $(m, \log \pi)$ table for the brighter apparent magnitudes by the same method as was used in the check on TABLE 9 from Malmquist's spectral distribution. When spectral classes become available to faint magnitude limits we shall be able to investigate changes in the luminosity function for various directions along the galactic equator.

TABLE 19

(m, log π) Table for $b = 0°$

r \ m	8	9	10	11	12	13	14	15	16	17	18	19		log V
10	7.03	7.11	7.19	7.24	7.29	7 33	7.37							9 31
16	7.40	7.50	7.58	7.66	7.71	7.76	7.80	7.84						9.78
25	7.88	8.00	8.10	8.18	8.26	8.31	8.36	8.40	8.44					0.38
40	8.33	8.48	8.60	8.70	8.78	8.86	8.91	8.96	9.00	9.04				0.98
63	8.77	8.93	9.08	9.20	9.30	9.38	9.46	9.51	9.56	9.60	9.64		M	1.58
100	9.04	9.37	9.53	9.68	9.80	9.90	9.98	0.06	0.11	0.16	0.20	0.24		2.18
158	9.55	9.64	9.97	0.13	0 28	0.40	0.50	0.58	0.66	0.71	0.76	0.80	+13	2.78
251	9.72	0.15	0.24	0.57	0.73	0.88	1.00	1.10	1.18	1.26	1.31	1.36		3.38
400	9.66	0.32	0.75	0.84	1.17	1.33	1.48	1.60	1.70	1.78	1 86	1.91	+11	3.98
630	9.65	0.26	0.92	1.35	1.44	1.77	1.93	2.08	2.20	2.30	2.38	2.46		4.58
1000	9.93	0.25	0.86	1.52	1.95	2.04	2.37	2.53	2.68	2.80	2.90	2.98	+9	5.18
1580	0.03	0.53	0.85	1.46	2.12	2 55	2.64	2.97	3.13	3.28	3.40	3.50		5.78
2500	0.03	0.63	1.13	1.45	2.06	2.72	3.15	3.24	3.57	3.73	3.88	4.00	+7	6.38
4000	0.05	0.63	1 23	1.73	2.05	2.66	3.32	3.75	3.84	4.17	4.33	4.48		6.98
6300		0.65	1.23	1.83	2.33	2.65	3.26	3.92	4.35	4.44	4.77	4.93	+5	7.58
10000			1.25	1.83	2.43	2.93	3.25	3.86	4.52	4.95	5.04	5.27		8.18
			−5		−3		−1		+1		+3			

TABLE 20

(m, log π) Table for b = 2°

z	r \ m	8	9	10	11	12	13	14	15	16	17	18	19		log V
0	10	7.03	7.11	7.19	7.24	7.29	7.33	7.37							9.31
0	16	7.40	7.50	7.58	7.66	7.71	7.76	7.80	7.84						9.78
1	25	7.88	8.00	8.10	8.18	8.26	8.31	8.36	8.40	8.44					0.38
1	40	8.33	8.48	8.60	8.70	8.78	8.86	8.91	8.96	9.00	9.04				0.98
2	63	8.77	8.93	9.08	9.20	9.30	9.38	9.46	9.51	9.56	9.60	9.64		M	1.58
4	100	9.04	9.37	9.53	9.68	9.80	9.90	9.98	0.06	0.11	0.16	0.20	0.24		2.18
6	158	9.54	9.64	9.97	0.13	0.28	0.40	0.50	0.58	0.66	0.71	0 76	0.80	+13	2.78
9	251	9.69	0.13	0.24	0.57	0.73	0.88	1.00	1.10	1.18	1.26	1.31	1.36		3.38
14	400	9.56	0.27	0.72	0.84	1.17	1.33	1.48	1.60	1.70	1.78	1.86	1.91	+11	3.98
22	630	9.43	0.11	0.82	1.30	1.42	1.77	1.93	2.08	2.20	2 30	2.38	2.46		4.58
35	1000	9.55	9.90	0.63	1.33	1.86	2.01	2.37	2.53	2.68	2.80	2.90	2.98	+9	5.18
55	1580	9.43	9.93	0.30	1.11	1.84	2.40	2.58	2.97	3.13	3.28	3 40	3 50		5 78
90	2500	9.16	9.76	0.26	0.63	1.54	2.30	2.87	3.11	3.55	3.71	3.87	3.90	+7	6.38
140	4000	8.90	9.48	0.08	0.58	0.96	1.94	2.72	3.28	3.59	4.02	4.23	4.39		6 98
220	6300		9.21	9.79	0.39	0.89	1.28	2.30	3.07	3.62	3.92	4.37	4.65	+5	7 58
350	10000			9.53	0.11	0.71	1.21	1.62	2.59	3.32	3.87	4.17	4.69		8.18
					−5		−3		−1		+1		+3		

TABLE 21

(m, log π) Table for $b = 4°$

z	r \ m	8	9	10	11	12	13	14	15	16	17	18	19		log V
1	10	7.03	7.11	7.19	7.24	7.29	7.33	7.37							9.31
1	16	7.40	7.50	7.58	7.66	7.71	7.76	7.80	7.84						9.78
2	25	7.88	8.00	8.10	8.18	8.26	8.31	8.36	8.40	8.44					0.38
3	40	8.33	8.48	8.60	8.70	8.78	8.86	8.91	8.96	9.00	9.04				0.98
4	63	8.77	8.93	9.08	9.20	9.30	9.38	9.46	9.51	9.56	9.60	9.64		M	1.58
7	100	9.04	9.37	9.53	9.68	9.80	9.90	9.98	0.06	0.11	0.16	0.20	0.24		2.18
11	158	9.53	9.64	9.97	0.13	0.28	0.40	0.50	0.58	0.66	0.71	0.76	0.80	+13	2.78
18	251	9.64	0.11	0.23	0.57	0.73	0.88	1.00	1.10	1.18	1.26	1.31	1.36		3.38
28	400	9.47	0.19	0.68	0.82	1.17	1.33	1.48	1.60	1.70	1.78	1.86	1.91	+11	3.98
44	630	9.20	9.96	0.69	1.25	1.40	1.77	1.93	2.08	2.20	2.30	2.38	2.46		4.58
70	1000	9.21	9.59	0.43	1.17	1.75	1.96	2.37	2.53	2.68	2.80	2.90	2.98	+9	5.18
110	1580	9.05	9.55	9.90	0.86	1.62	2.20	2.46	2.90	3.08	3.23	3.35	3.45		5.78
175	2500	8.75	9.35	9.85	0.23	1.23	2.00	2.55	2.88	3.32	3.54	3.73	3.86	+7	6.38
280	4000	8.47	9.05	9.65	0.15	0.53	1.54	2.30	2.85	3.14	3.63	3.92	4.18		6.98
440	6300		8.78	9.36	9.96	0.46	0.85	1.83	2.55	3.10	3.39	3.94	4.23	+5	7.58
700	10000			8.92	9.50	0.10	0.60	0.98	1.96	2.72	3.30	3.57	4.17		8.18
					−5		−3		−1		+1		+3		

TABLE 22

(m, log π) Table for b = 6°

z	r \ m	8	9	10	11	12	13	14	15	16	17	18	19	M	log V
1	10	7.03	7.11	7.19	7.24	7.29	7.33	7.37							9.31
2	16	7.40	7.50	7.58	7.66	7.71	7.76	7.80	7.84						9.78
3	25	7.88	8.00	8.10	8.18	8.26	8.31	8.36	8.40	8.44					0.38
4	40	8.33	8.48	8.60	8.70	8.78	8.86	8.91	8.96	9.00	9.04				0.98
7	63	8.77	8.93	9.08	9.20	9.30	9.38	9.46	9.51	9.56	9.60	9.64		M	1.58
10	100	9.04	9.37	9.53	9.68	9.80	9.90	9.98	0.06	0.11	0.16	0.20	0.24		2.18
17	158	9.51	9.63	9.97	0.13	0.28	0.40	0.50	0.58	0.66	0.71	0.76	0.80	+13	2.78
26	251	9.59	0.08	0.22	0.57	0.73	0.88	1.00	1.10	1.18	1.26	1.31	1.36		3.38
42	400	9.38	0.10	0.64	0.79	1.17	1.33	1.48	1.60	1.70	1.78	1.86	1.91	+11	3.98
65	630	9.02	9.86	0.60	1.17	1.36	1.77	1.93	2.08	2.20	2.30	2.38	2.46		4.58
100	1000	9.00	9.37	0.31	1.06	1.63	1.89	2.32	2.50	2.66	2.78	2.88	2.97	+9	5.18
160	1580	8.80	9.30	9.68	0.66	1.45	2.01	2.33	2.77	2.98	3.16	3.30	3.42		5.78
260	2500	8.48	9.08	9.58	9.98	0.99	1.75	2.31	2.59	3.07	3.36	3.61	3.80	+7	6.38
420	4000	8.22	8.80	9.40	9.90	0.28	1.26	1.98	2.53	2.84	3.37	3.67	4.00		6.98
660	6300		8.39	8.97	9.57	0.07	0.45	1.44	2.20	2.75	3.03	3.62	3.88	+5	7.58
1000	10000			8.40	8.98	9.58	0.08	0.45	1.43	2.24	2.87	3.19	3.74		8.18
					−5		−3		−1		+1		+3		

TABLE 23

(m, log π) Table for $b = 8°$

z	r \ m	8	9	10	11	12	13	14	15	16	17	18	19		log V
1	10	7.03	7.11	7.19	7.24	7.29	7.33	7.37							9.31
2	16	7.40	7.50	7.58	7.66	7.71	7.76	7.80	7.84						9.78
4	25	7.88	8.00	8.10	8.18	8.26	8.31	8.36	8.40	8.44					0.38
6	40	8.33	8.48	8.60	8.70	8.78	8.86	8.91	8.96	9.00	9.04				0.98
9	63	8.77	8.93	9.08	9.20	9.30	9.38	9.46	9.51	9.56	9.60	9.64		M	1.58
13	100	9.04	9.37	9.53	9.68	9.80	9.90	9.98	0.06	0.11	0.16	0.20	0.24		2.18
22	158	9.50	9.63	9.97	0.13	0.28	0.40	0.50	0.58	0.66	0.71	0.76	0.80	+13	2.78
35	251	9.54	0.06	0.21	0.57	0.73	0.88	1.00	1.10	1.18	1.26	1.31	1.36		3.38
55	400	9.31	0.04	0.60	0.78	1.17	1.33	1.48	1.60	1.70	1.78	1.86	1.91	+11	3.98
90	630	8.83	9.74	0.50	1.07	1.31	1.75	1.91	2.08	2.20	2.30	2.38	2.46		4.58
140	1000	8.78	9.17	0.14	0.92	1.49	1.79	2.22	2.43	2.58	2.72	2.83	2.96	+9	5.18
220	1580	8.59	9.09	9.48	0.50	1.27	1.82	2.12	2.57	2.85	3.08	3.25	3.36		5.78
350	2500	8.31	8.91	9.41	9.81	0.79	1.52	2.07	2.38	2.89	3.20	3.48	3.72	+7	6.38
560	4000	7.97	8.55	9.15	9.65	0.03	1.01	1.76	2.30	2.61	3.19	3.45	3.80		6.98
880	6300		8.00	8.58	9.18	9.68	0.07	1.04	1.82	2.44	2.72	3.31	3.56	+5	7.58
1400	10000			7.65	8.23	8.83	9.33	9.75	0.71	1.57	2.28	2.68	3.14		8.18
					−5		−3		−1		+1		+3		

TABLE 24

(m, log π) Table for $b = 10°$

z	r \ m	8	9	10	11	12	13	14	15	16	17	18	19		log V
2	10	7.03	7.11	7.19	7.24	7.29	7.33	7.37							9.31
3	16	7.40	7.50	7.58	7.66	7.71	7.76	7.80	7.84						9.78
4	25	7.88	8.00	8.10	8.18	8.26	8.31	8.36	8.40	8.44					0.38
7	40	8.33	8.48	8.60	8.70	8.78	8.86	8.91	8.96	9.00	9.04				0.98
11	63	8.77	8.93	9.08	9.20	9.30	9.38	9.46	9.51	9.56	9.60	9.64		M	1.58
17	100	9.04	9.37	9.53	9.68	9.80	9.90	9.98	0.06	0.11	0.16	0.20	0.24		2.18
27	158	9.49	9.62	9.97	0.13	0.28	0.40	0.50	0.58	0.66	0.71	0.76	0.80	+13	2.78
44	251	9.49	0.05	0.19	0.57	0.73	0.88	1.00	1.10	1.18	1.26	1.31	1.36		3.38
70	400	9.23	9.97	0.55	0.76	1.17	1.33	1.48	1.60	1.70	1.78	1.86	1.91	+11	3.98
110	630	8.70	9.66	0.42	1.00	1.26	1.70	1.88	2.03	2.15	2.25	2.37	2.46		4.58
175	1000	8.65	9.03	0.03	0.80	1.35	1.67	2.12	2.34	2.53	2.70	2.80	2.94	+9	5.18
270	1580	8.45	8.95	9.35	0.36	1.13	1.68	1.96	2.45	2.73	3.00	3.20	3.32		5.78
430	2500	8.18	8.78	9.28	9.67	0.65	1.37	1.92	2.21	2.76	3.05	3.38	3.63	+7	6.38
700	4000	7.72	8.30	8.90	9.40	9.78	0.76	1.52	2.10	2.37	2.97	3.22	3.63		6.98
1100	6300		7.62	8.20	8.80	9.30	9.68	0.66	1.47	2.12	2.46	3.00	3.26	+5	7.58
1700	10000			7.17	7.75	8.35	8.85	9.23	0.21	1.02	1.67	2.01	2.55		8.18
					−5		−3		−1		+1		+3		

SUMMARY

A study is made of the stellar distribution over the north galactic polar cap. The basic material consists of general starcounts, mean parallaxes, spectral data and the general luminosity function in the galactic plane. The resultant (m, log π) table (TABLE 9) gives that distribution in distance for stars of successive apparent magnitudes which is most nearly consistent with the observations. As a by-product of the investigation we have derived the density gradients perpendicular to the galactic plane for stars of different absolute magnitudes (FIGURE 4).

We present a modification of the Oort-Vashakidse method, which for a field in intermediate latitudes allows the rapid and accurate computation of the star densities at various heights above or below the galactic plane. The method is applied to the analysis of star-counts in a number of regions for which the absorption is well known (FIGURES 7 to 14).

For convenience we reproduce the (m, log π) tables for low galactic latitudes, suggested by the present investigation.

THE ABSORPTION COEFFICIENT AND THE LUMINOSITY CURVE IN THE GALACTIC PLANE

By Jan Schilt

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In this paper the coefficient of absorption is derived for the case that this coefficient is a constant and that the stellar density is uniform throughout a thin layer along the galactic plane. Such a simple theory, although known not to apply in detail to our galaxy, is likely to give a reasonably good average value, if applied to observations averaged over all galactic longitudes. The results are based on the counts of stars of a given apparent magnitude and since these include stars at widely different distances, the results are not apt to be influenced by irregularities in the density extending over distances of the order of ten or even a hundred parsecs. The fact that some observers find a local cluster and that others find indication of a local region of avoidance seems to justify the stated case at the present stage of our knowledge. On the basis of a rotational symmetry in the stellar system the "uniform" theory could be expected to correspond to the actual case for directions 90° away from the galactic center.

If we adopt as unit of distance the distance at which a star undergoes an absorption of one magnitude and if we denote the absolute magnitude relative to this distance by M we can compute the relative numbers of stars brighter than m whose absolute magnitude is M. Putting $5 \log r = \rho$, we have

$$m - \mathsf{M} = \rho + 10^{0.2\rho} \tag{1}$$

and $F\ (m - \mathsf{M}) = 10^{0.6\rho}$ has been computed for values of $m - \mathsf{M}$ from -15 to $+15$ (See TABLE 1). By differencing F we obtain

$$f\ (m - \mathsf{M} + \tfrac{1}{2}) = F\ (m - \mathsf{M} + 1) - F\ (m - \mathsf{M})$$

giving the relative numbers of stars between given intervals of the argument $m - \mathsf{M}$. The logarithm of f is given in the third column of TABLE 1. We now have for the number of stars of magnitude m per square degree

$$A_m = \int 10^{\log f(m-\mathsf{M}) + \log \Phi\ (\mathsf{M})}\, d\mathsf{M} \tag{2}$$

$$\overline{\Pi}_m = 1/A_m \int 10^{\log f(m-\mathsf{M}) - \frac{1}{5} \log F(m-\mathsf{M}) + \log \Phi\ (\mathsf{M})}\, d\mathsf{M} \tag{3}$$

The sum of the first two terms in the exponent of (3) is tabulated in the fourth column of TABLE 1. Φ (M) is the number of stars of absolute magnitude M inside a solid angle of one square degree and unit radius. The left members of the two integral equations can now be computed for any given Φ (M). If A_m is known Φ (M) can be computed from (2) and subsequently $\overline{\Pi}_m$ from (3). From $\bar{\pi}_m$, the mean parallax in units of parsec^{-1}, the coefficient of absorption is found as $\bar{\pi}_m \div \overline{\Pi}_m$ in units of magnitudes per parsec.

In the application of this method I have first used the starcounts by photographic magnitudes given by van Rhijn[1] for zero latitude. For the brighter magnitudes these counts are derived from visual Harvard magnitudes and Pannekoek's counts of the Bonn and Cordoba Durchmusterung, because at the time photographic magnitudes for the brighter stars were lacking. Such magnitudes have now become available in the results for the Zone Catalogs,[2] and by means of them slight corrections to van Rhijn's counts for the stars brighter than the tenth magnitude have been derived and applied. For the actual computations it is desirable to use an interpolation formula for log Φ. As a suitable one not introducing too many constants we take

$$\log \Phi = -a\,(\mathsf{M} - b)^2 + c.$$

Only if A_m is believed to be systematically correct to better than 10 per cent would it be necessary to introduce higher order terms. Adopting a given value for a the constants b and c are determined from the observed log A_m. Since

$$A_m = \int 10^{\log f(m-\mathsf{M}) - a(\mathsf{M}-b)^2 + c}\, d\mathsf{M}$$

we have (putting first $\mathsf{M} - b = \mathsf{M}'$ and subsequently omitting the primes)

$$A_{m-b} = 10^c \int 10^{\log f(m-b-\mathsf{M}) - a\mathsf{M}^2} d\mathsf{M}$$

$$\log A_{m-b} - c = \log \int 10^{\log f(m-b-\mathsf{M}) - a\mathsf{M}^2} d\mathsf{M}$$

which determines b and c. In other words, the computed curve $\log A - c$ for the argument $m - b$ is shifted along the axes of abscissae and ordinates so as to make it coincide with the observed curve for $\log A_m$.

The computations have been carried through for four cases. In solutions I, II and III, $2a$ has the values .025, .035, .062, respectively,

[1] Groningen Publ. No. 43. 1929. Table 6.

[2] Trans. Astr. Obs. Yale Univ. 4. 1925; 7. 1930; 9. 1932; 10. 1934; 11. 1939; 12. 1940.

and in solution IV we have the limiting case that all stars have the same absolute magnitude. The results are in TABLE 3. In the upper half we see from solution IV that if we take $2a$ too large, the computed numbers for the faint stars are too small. Solutions I and II give a good representation of the starcounts; still smaller values of $2a$ would show a systematic deviation opposite to that of III and IV. If the "uniform" theory applies, the mean computed parallaxes in solutions I and II should be in a constant ratio to the observed ones.

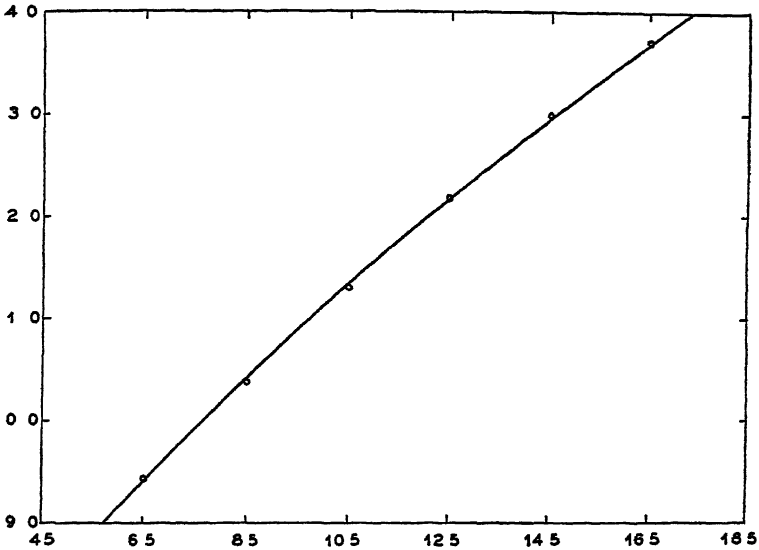

FIGURE 1. Abscissae: Photographic magnitudes. Ordinates: log A_m. The curve represents the average of solutions I and II. Open circles represent observed counts by Van Rhijn.

This is beautifully confirmed. The logarithm of this ratio decreases slowly in one and increases slowly in the other solutions, so that the theoretically correct one lies between the two. The constant -3.00 gives the coefficient of absorption as exactly 1 magnitude per 1000 parsecs.

FIGURE 1 shows the observed starcounts and the theoretical curve corresponding to our solutions I and II. The various symbols in FIGURE 2 show the observed mean parallaxes which are described in a number of notes at the end of this paper.

If instead of van Rhijn's counts we use Seares's[3] the results are as

[3] Contr. Mt. Wilson Obs. 13: 383. 1925.

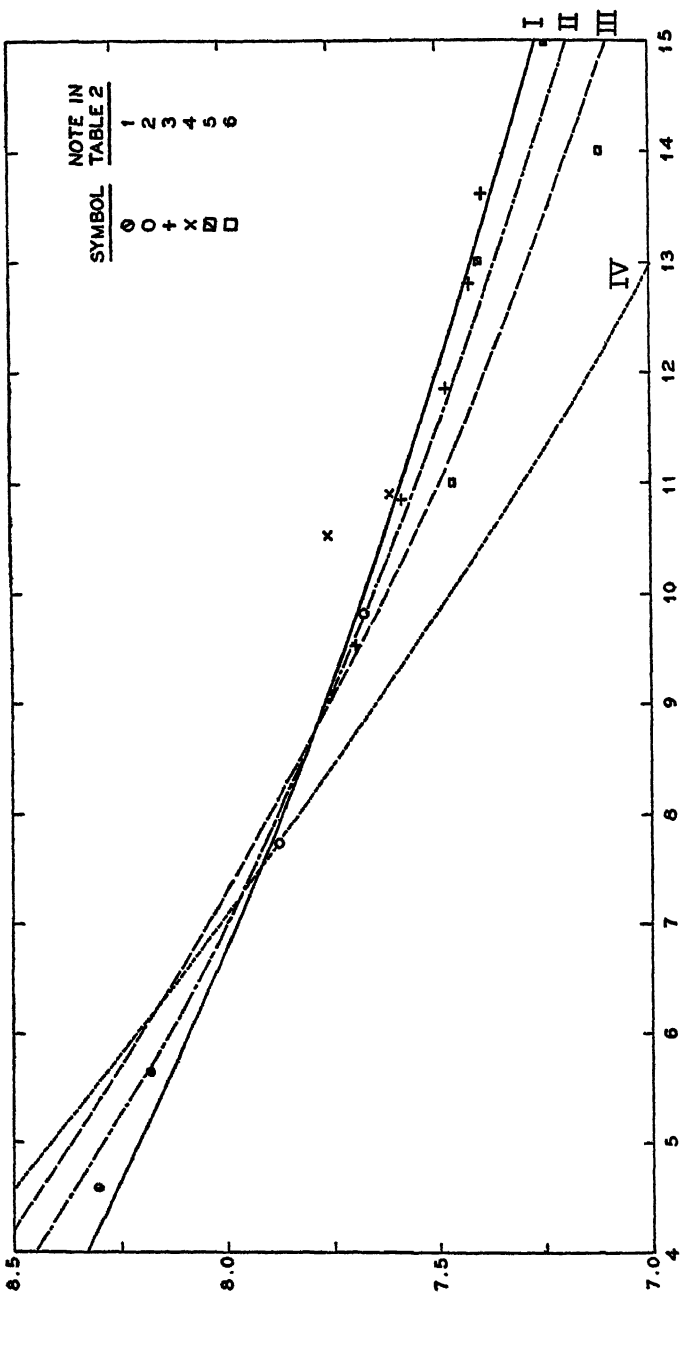

FIGURE 2. Abscissae: Photographic magnitudes. Ordinates: Log mean parallax. The curves I to IV correspond to the solutions of Table 3. Various symbols denote observed mean parallaxes in table 2.

given in TABLE 3a. It is seen in the upper part of this table that solution I gives the best representation of the starcounts. The use of a smaller modulus would make the computed numbers for stars of intermediate magnitudes too small. Solution II is not quite as good but it cannot be said to violate the observations. A still larger modulus as used in III definitely does not represent the observations. As to the mean parallaxes, the lower part of TABLE 3a shows almost perfect agreement with the observations for solution II. In the case of TABLE 3 we found that both the starcounts and the mean parallaxes point to a solution for the luminosity function intermediate between I and II. The agreement in the case of TABLE 3a is not quite as good but here we have been more exacting by using starcounts for a larger range of magnitudes. For practical purposes the difference between solutions I and II is small, and this is shown in FIGURE 3. TABLES 3 and 3a show that equation (2) is primarily sensitive to the curvature and equation (3) to the slope of the luminosity function. If we adopt solution II for the case of Seares's counts the coefficient of absorption π/Π is found, since $\log \pi/\Pi = -2.84$, to be 1.45 magnitudes per 1000 parsecs.

The luminosity functions based on van Rhijn's counts and solutions I and II and the one based on Seares's counts and solution II as given in FIGURE 3, have been reduced to the ordinary argument M and the volume of one cubic parsec. The same material is given in tabular form for solutions I and II (van Rhijn's counts) and II (Seares's counts) together with the luminosity function derived by van Rhijn[4] in TABLE 4.

It thus appears that van Rhijn's and Seares's starcounts on the basis of the present theory lead to very similar luminosity functions and to rather different absorption coefficients. For the brightest stars the new luminosity function is close to van Rhijn's. The number of stars of absolute magnitudes $+5$ and fainter appears to be very much larger than according to the classical luminosity functions and at magnitude $+8$ the results give ten times as many stars. This enormous difference is essentially a consequence of the revision of the mean parallaxes of the faint stars. Such a revision, however, seems imperative on observational grounds and is also backed by theoretical considerations, which enable us to compute the shape of the function $\log \pi_m$ for the general case of a constant absorption coefficient.

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[4] Groningen Publ. No. 47. 1936. TABLE 6.

The relative importance of the contribution of stars of various absolute magnitudes to the number of stars of given apparent magnitudes is illustrated in FIGURE 4. On the basis of the Groningen luminosity function the maximum in the frequency of M for stars of

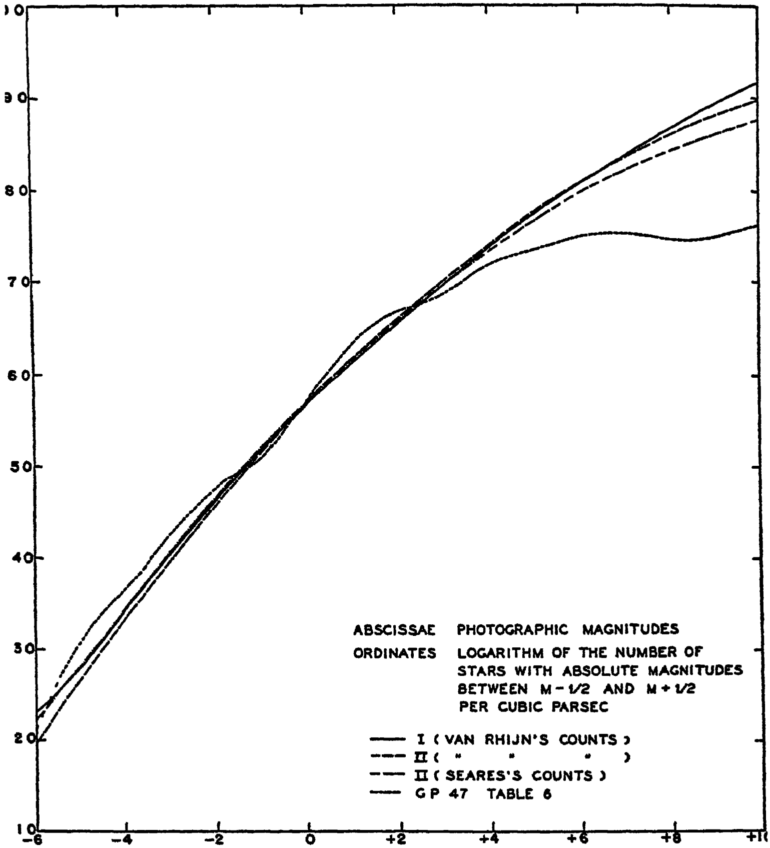
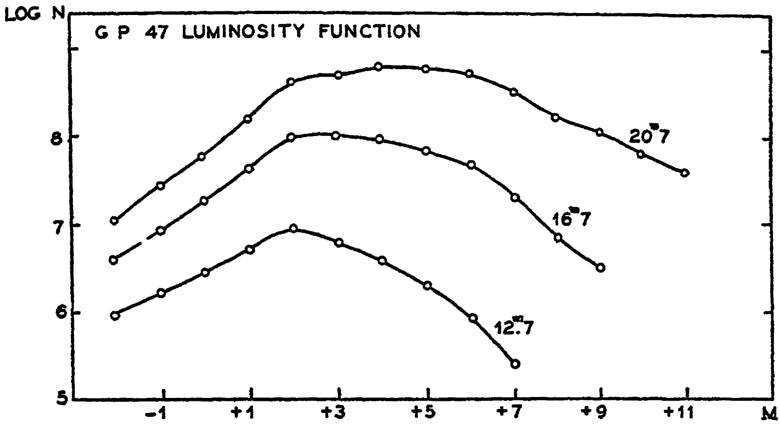


FIGURE 3

given m varies slowly from about $+2$ for $m = 12$ to about $+4$ for $m = 20$; for $m = 17$ it is around $+3$. This would mean that most of the 17th magnitude stars in the galactic plane are still of spectral types early F. On the basis of the present luminosity function the maximum in the frequency of M for stars of the 12th magnitude is also about $+2$. Passing on to fainter stars, however, the maximum moves much faster than according to the Groningen luminosity func-



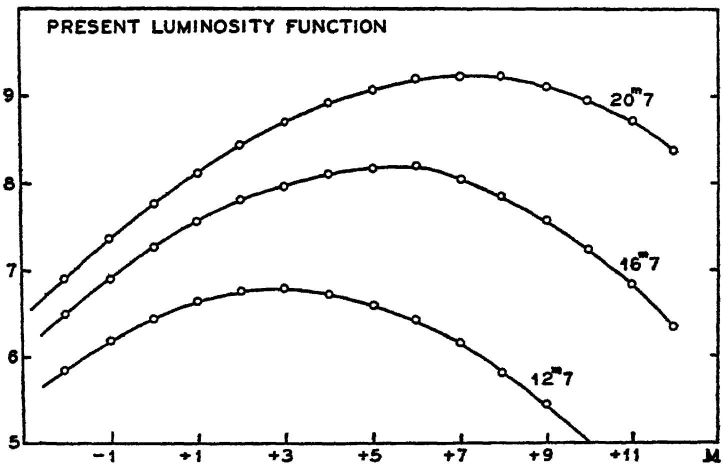


FIGURE 4. Apparent magnitudes for curves are for absorption coefficient 1.45. In general they are for $\begin{cases} 11^m.5 - 5 \text{ (log abs.} + 1) \\ 7\ .5 - 5 \text{ (log abs.} + 1) \\ 3\ .5 - 5 \text{ (log abs.} + 1) \end{cases}$

tion, reaching $+7$ for $m = 20$. For $m = 17$ it is around $+5$, indicating a spectral type G. Even stars as faint as the 20th magnitude show only one star of $M = +12$ to every ten of $M = +7$ and the present luminosity function consequently is not significant beyond, say, $+11$, and in the range from $+8$ to $+11$ the uncertainty is large. An increase over the classical luminosity function, however, sets in already at $+4$, indicating a far greater number of G and K

stars, not to mention the still fainter ones. The most direct way to settle this point, I believe, is actually to obtain the spectra for a fair number of stars of photographic magnitudes 16 or even 17 picked at random over the galactic plane. With some of the exceedingly fast instruments now available this would not seem an impossible task.

A change from the classical luminosity function to the present one would necessitate a revision of the stellar mass per cubic parsec. Using the present luminosity function extrapolated to stars of magnitude 14.5 and the estimated masses for stars of given absolute magnitude in correspondence with Oort's Table 34[5] the result is 0.38 solar masses per cubic parsec, the maximum contribution being from stars of absolute magnitude 11. In envisaging such a high value we have to take into consideration that the layer for which the present results are derived need not be over 200 parsecs thick and that the total mass contained in a cylinder perpendicular to the galactic plane and with unit cross-section need not be very much larger than the value derived by Oort.[5] Since the total luminosity per cubic parsec depends largely on the very bright stars, this quantity would not materially be altered by the present results.

NOTES CONCERNING THE OBSERVED MEAN PARALLAXES

1. The proper motions of the PGC are used. The original values obtained in Groningen Publication 29 have been revised by the application of the correction of Boss and Jenkins amounting to $-''.0030$ in the mean secular parallax. The material used for the fainter stars, summarized in TABLE 2 of GP 45, is in part incorporated in the discussions of the zone catalogs (see note 2), in part it is superseded by the work of van de Kamp and Vyssotsky. The results from the Groombridge Catalog combined into two points give log $(\overline{h/\rho}) = 8.594$ at $m_{pg} = 7.1$ and 8.489 at 9.1. This catalog, extending from the north pole to $+38°$, covers only a small portion of the galactic regions and its weight has become negligible in the determination of the mean parallaxes. No weight has been given to it in the present discussion.

2. In an unpublished paper the mean secular parallaxes have been computed from the proper motions in the various Yale Zone Catalogs. These proper motions have been reduced to the system of the FK3 (see Astronomical Journal in press). The method used is analogous

[5] Bull. Astr. Inst. Netherlands 6: 285. 1932.

to that of the v-components, but instead of using the full amount of the parallactic drift I use its component at right angles to the direction of rotation of the stellar system. The purpose of this change from the classical method is to obviate the effect of the asymmetry in stellar motions and it is expected that the element of uncertainty in the amount of solar velocity depending on the brightness of the stars is largely overcome.

3. The mean parallactic motions of the fainter stars in the original investigation at Groningen are very uncertain[6] and the necessity of referring faint proper motions directly to the bright stars was realized by Kapteyn from the start. It was primarily with this purpose in view that first Alden and Van de Kamp and later Van de Kamp and Vyssotsky undertook their extensive programs of measuring and discussing the proper motions of faint stars on parallax plates. For the stars between latitudes $\pm 10°$ the results are based on 8461 stars in 80 regions centered on parallax stars. As a consequence of the reduction in the strength of the images of the parallax stars the results should be largely free of magnitude errors and they should have considerable weight especially in the determination of the slope of the mean parallax curve. Still we cannot be certain that the system as determined by the 80 regions ranging in galactic longitude from about 340° to 200° is identical to that of the bright stars for the entire sky. For the reduction to mean parallaxes I have used the values for the solar motion as adopted by Van de Kamp and Vyssotsky[7], which show a slight increase with increasing magnitude.

4. The reference stars of the Allegheny and Johannesburg parallax plates cover almost the entire sky. The drawback of this determination is that only proper motions in right ascension have been measured. However, this circumstance in a way adds to the systematical independence of the result. It is worth noting that the result for the McCormick reference stars, which are restricted in galactic longitude, is above the average value for photographic magnitude 10.5. (See also Van de Kamp and Vyssotsky[6] page 28.)

5. Still fainter stars are reached in the Radcliffe proper motions for the Northern Selected Areas. These are relative proper motions, and the extension by this means of the mean secular parallaxes is based on the Allegheny and Johannesburg reference stars. The result gives a striking confirmation of the slope of the mean secular

[6] Groningen Publ. No. 29. 1918.
[7] Publ. Leander McCormick Obs 7. 1937.

parallax curve as determined by the McCormick proper motions. See note 3.

6. Oort finds a value of $d \log \bar{\pi}/dm$ numerically twice as large as obtained from the average of all other determinations for faint stars. The mean parallax is derived from the dispersion in the proper motions of the Radcliffe stars and on the dispersion of the linear velocities of stars of similar magnitudes. This method avoids the uncertainty of reducing the relative proper motions to absolute, which is a great advantage especially in the case of faint stars where they are small. On the other hand, there are two new sources of uncertainty in Oort's method that may well outweigh its advantages. The first one is the correction of the observed dispersion in the proper motions for the effect of observational errors, the second the uncertainty in the linear velocities. Radial velocities for the faint stars have been observed in relatively few cases, too few to be of use in a statistical discussion, and therefore Oort has used hypothetical values based on the radial velocities of bright stars of different spectral types and on the knowledge of the spectral distributions, including the distribution of giants and dwarfs for stars of a given magnitude. As to the interpretation of the results, Oort draws attention in his figure 3 to the linearity of the values of $\log \bar{\pi}_m$ with the magnitude. The least-squares solution results in $d \log \bar{\pi}_m/dm = -.132$* for the group of smallest galactic latitude, and almost the same values for the groups of median and high latitude. In my opinion the first group at any rate shows very little evidence of a linear character, and aside from the possible theoretical considerations that $d \log \pi/dm$ should be a constant, the determination is rather weak.**

* This is exactly the value derived by Van Rhijn and Bok in GP 45. The older value by Kapteyn, Van Rhijn, & Weersma in GP 29 is −0.1697.

** In his solution Oort has rejected the last point for magnitude 14 8 which, although its probable error is the smallest of all, is supposed to be uncertain on account of the smallness of the proper motions. This may very well be so, but the uncorrected average proper motions are the same, viz., ″.0065, for both $14^m.8$ and $14^m.0$. The result of the least-squares solution *including* the last point is $d \log \bar{\pi}_m/dm = -.0905$ and *excluding* the two last points it is −.161.

TABLE 1

$m - \mathbf{M}$	10+ log $F(m - \mathbf{M})$	10+ log $f(m - \mathbf{M})$	10+ log $f(m - \mathbf{M})$ −1/3 log $F(m - \mathbf{M})$
−15	0.9994		
		1.4732	4.3734
−14	1.5990		
		2 0727	4.7731
−13	2.1985		
		2.6717	5.1723
−12	2.7976		
		3 2701	5 5711
−11	3.3962		
		3 8678	5.9694
−10	3.9941		
		4.4638	6.3664
− 9	4.5906		
		5.0576	6.7616
− 8	5.1851		
		5 6479	7.1543
− 7	5.7765		
		6 2330	7.5390
− 6	6.3632		
		6.8098	7.9255
− 5	6.9426		
		7.3745	8.2989
− 4	7.5112		
		7.9216	8.6590
− 3	8.0642		
		8 4446	9.0013
− 2	8 5958		
		8 9360	9.3202
− 1	9.0994		
		9 3891	9.6111
0	9.5690		
		9.7989	9.8707
+ 1	10.0000		
		10.1634	10 0984
+ 2	10.3904		
		10.4837	10 2952
+ 3	10.7406		
		10.7636	10 4646
+ 4	11.0533		
		11.0076	10.6100
+ 5	11.3321		
		11.2207	10.7351
+ 6	11.5810		
		11.4078	10 8436
+ 7	11.8040		
		11.5732	10.9384
+ 8	12.0048		
		11.7204	11.0218
+ 9	12.1865		
		11.8522	11.0958
+10	12.3518		
		11.9714	11.1622
+11	12.5030		
		12 0792	11.2217
+12	12.6419		
		12.1780	11.2760
+13	12.7702		
		12 2688	11.3255
+14	12.8892		
		12.3525	11.3719
+15	13.0000		

TABLE 2

m_{pg}	10+ log π	Notes	Authority
4.60	8.308	1	Van Rhijn and Bok[8]
5.65	8.181	1	Van Rhijn and Bok[8]
7.74	7.871	2	Schilt, unpublished
9.81	7.678	2	Schilt, unpublished
9.52	7.691	3	Van de Kamp and Vyssotsky, Table 6.1[7]
10.84	7.586	3	Van de Kamp and Vyssotsky, Table 6.1[7]
11.84	7.472	3	Van de Kamp and Vyssotsky, Table 6.1[7]
12.79	7.425	3	Van de Kamp and Vyssotsky, Table 6.1[7]
13.59	7.397	3	Van de Kamp and Vyssotsky, Table 6.1[7]
10.55	7.752	4	McCormick reference stars
10.9	7.612	4	Allegheny reference stars
13.9	7.403	5	Van de Kamp and Vyssotsky, Table 6.7, mean of two brightest groups[7]
15.0	7.249	5	Van de Kamp and Vyssotsky, Table 6.7, mean of two faintest groups[7]
11.0	7.466	6	Oort, Table 11, mean of 3 brightest groups[9]
14.0	7.119	6	Oort, Table 11, mean of 3 faintest groups[9]

[8] Groningen Publ. No. 45. 1931.
[9] Bull. Astr. Inst. Netherlands 8: 75. 1936.

TABLE 3

UPPER PART GIVES log A_m Obs. − Comp.

LOWER PART GIVES log $\bar{\pi}_m$ − log $\overline{\Pi}_m$

Solution	I (.025)	II (.035)	III (.062)	IV (∞)	Observed per square degree
Δ log $A_{6.5}$	−0.010	+0.032	+0.054	+0.109	9.435
8.5	−0.033	−0.019	−0.043	−0.058	0.380
10.5	−0.012	−0.022	−0.029	−0.142	1.310
12.5	+0.021	0.000	−0.018	−0.119	2.196
14.5	+0 031	+0.004	+0.005	0.000	3.000
16.5	+0.009	+0.008	+0.031	+0.187	3.711
					Observed log $\bar{\pi}$
5.5	−2.97	−3.03	−3.10	−3.13	8.18
7.5	−3.01	−3.02	−3.06	−3.01	7.91
9.5	−3.02	−3.01	−2.99	−2.86	7.70
11.5	−3.02	−2.98	−2.92	−2.70	7.52
13.5	−3.02	−2.96	−2.88	−2.58	7.36
15.5	−3.02	−2.95	−2.83	−2.49	(7.21)

TABLE 3A

SEARES'S SCALE

Solution	I	II	III	Observed per square degree
Δ log $A_{5.5}$	+0.043	+0 062	+0.120	8 920
7.5	−0.016	−0.023	−0 028	9 814
9.5	−0.035	−0.063	−0 068	0.690
11.5	−0 024	−0.060	−0.093	1 540
13 5	+0.010	−0.018	−0 062	2.352
15.5	+0.029	+0.019	−0 010	3 089
17.5	+0 017	+0.040	+0 045	3.734
19 5	−0.026	+0.039	+0.098	4 287
				Observed log ≂
5.5	−2.79	−2.82	−2 94	8.18
7.5	−2 86	−2.85	−2 91	7.91
9.5	−2.88	−2 85	−2 86	7.70
11.5	−2.89	−2.84	−2.82	7.52
13.5	−2.90	−2.84	−2.78	7.36
15.5	−2.92	−2.84	−2 75	(7.21)

TABLE 4

THE LOGARITHM OF THE NUMBER OF STARS WITH PHOTOGRAPHIC ABSOLUTE MAGNITUDES BETWEEN $M - \frac{1}{2}$ AND $M + \frac{1}{2}$ PER CUBIC PARSEC

M	log ϕ (M) + 10			
	I (van Rhijn)	II (van Rhijn)	II (Seares)	GP 47 Table 6
− 6	2.311	1.959	2.132	2.10
− 4	3.420	3.328	3.452	3.65
− 2	4.629	4.557	4.632	4.75
0	5.638	5.646	5.672	5.68
+ 2	6.547	6.595	6.572	6.77
+ 4	7.356	7.404	7.332	7.19
+ 6	8.065	8.073	7.952	7.49
+ 8	8.674	8.602	8.432	7.46
+10	9.183	8.991	8.772	7.64
+12	9.592	9.240	8.972	7.97
+14	9.701	9.349	9.032	8.06

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
VOLUME XLII, ART. 3. PAGES 273–360
NOVEMBER 15, 1941

STUDIES ON THE ORIGIN AND EARLY EVOLUTION OF PAIRED FINS AND LIMBS*:

PART I. Paired fins and girdles in Ostracoderms, Placoderms, and other primitive fishes

PART II. A new Restoration of the skeleton of *Eusthenopteron* (Pisces Crossopterygii, Devonian, Quebec) with Remarks on the Origin of the Tetrapod Stem

PART III. On the Transformation of Pectoral and Pelvic Paddles of *Eusthenopteron* type into Pentadactylate Limbs

PART IV. A new Theory of the Origin of the Pelvis of Tetrapods

BY
WILLIAM K. GREGORY AND HENRY C. RAVEN

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*Publication made possible through a grant from the income of the Ralph Winfred Tower Memorial fund.

PART I

PAIRED FINS AND GIRDLES IN OSTRACODERMS, PLACODERMS, AND OTHER PRIMITIVE FISHES

How did the paired fins and girdles of the earlier vertebrates arise? This classic and perennial question is gradually being answered by converging investigations in the fields of palaeontology, comparative anatomy and embryology. To cite only some of the later contributions to the subject, we may mention: (1) the numerous discoveries of Dr. Lauge Koch and his staff (especially Stensiö and Säve-Söderbergh) among the Devonian fishes of East Greenland; (2) the valuable papers by Watson, Westoll, Moy-Thomas, and others on the Devonian fishes of Great Britain and eastern Canada; (3) the careful descriptions of ontogenetic stages in the limbs of recent amphibians by Schmalhausen, Steiner, and Holmgren; (4) the intensive and extensive analyses of the interrelations of nerves, muscles, and skeletal parts in the pectoral girdle and limbs of vertebrates by Brazier Howell; (5) the description of the pectoral girdle and limb of the lower Carboniferous fish *Sauripterus* by one of us; (6) the synthesis of palaeontological and morphological data by Romer and Byrne. All this has brought the general problem to a critical phase which will be discussed below.

The problem of the origin and evolution of the paired appendages and girdles has usually been considered as if it could be settled by itself, but inasmuch as these structures are merely parts of an organic whole the question of their derivation is obviously connected with other problems relating to the several ways in which the known fossil and recent amphibians may have derived the complex patterns of their skulls, vertebral columns, brains, circulatory systems, and the like. This in turn is but part of a still larger picture of the origins and subsequent histories of all the lower classes of vertebrates. In the latter field the cumulative result of more than a century of investigation is now quite rapidly revealing the broad outlines, although there is still great need for more precise knowledge of details.

The oldest forerunners of the fishes and higher vertebrates known to palaeontologists are the Palaeozoic ostracoderms. These forms are barely indicated in the Ordovician and are chiefly represented near the close of their range in the upper Silurian and Devonian. It used to be customary to dismiss them as aberrantly specialized early side branches of the vertebrate stock, but through many explorations and discoveries of the past few decades it has been established that the ostracoderms belong to a

great superclass, Agnatha, which on the whole preceded the typical fishes and is remotely ancestral to the existing cyclostomes (lampreys and hags).

The entire cephalo-thorax of the earlier ostracoderms was covered with a shield of some sort, ultimately composed of tubercles that are comparable with placoid denticles, but resting on a tough skeletal integument well supplied with nutrient vessels and with a stratified skeletal base. Bone cells with Haversian canals are found in one major branch (the Cephalaspidomorphi), but not in the other (Pteraspidomorphi). In the former the shield is not divided into separate plates. In the latter it is composed of five main plates (one rostral, one mediandorsal, one medianventral, one pair of laterals). It used to be assumed that the presence of these plates was a specialization which excluded the ostracoderms from ancestry to higher types, but we wish to put forward the thesis that the covering plates of the pectoral girdle of placoderms and true fishes have been derived by reduction from the thoracic armor of ostracoderms, just as the covering plates of their skulls have been derived from the cephalic plates of ostracoderms.

In the Cephalaspidomorphi there are sometimes lateral fleshy lobes or projections on either side, medial to the posterior cornua of the shield. Stensiö (1927: 231) has also demonstrated the presence of a transverse skeletal septum (*op. cit.*, fig. 12, p. 45, *p. sh.*) behind the oralo-branchial chamber, which he regards as being at least analogous with the endoskeletal shoulder-girdle in fishes. The more median part of this osseous septum passed behind the pericardium, while the lateral parts lay well behind the postbranchial wall. Thus this septum is at least analogous to the septum transversum of the embryos of sharks and higher vertebrates (*cf.* Goodrich 1930: 614). We, however, suggest that the endoskeletal portion of the shoulder-girdle of fishes is an ingrowth from the basal pieces of the pectoral fins.

In another branch of the ostracoderms (certain Anaspida) Kiaer (1924: 103) demonstrated the presence of a paired row of spines on the ventral surface, converging from behind the last gill opening to the anal fin spines. This suggests a similar arrangement in certain acanthodians. Hence the beginnings of the system of paired fins and even of the pectoral girdle are already discernible among the oldest known agnathous vertebrates. According to Heintz (1931) the most primitive of the Placodermi are the acanthaspids, which have huge, outwardly and backwardly directed pectoral spines springing from the anterobasal lateral corners of the thoracic shield. We suggest that this condition also is relatively primitive even for the true fishes.

The acanthodians of the lower Devonian likewise used to be regarded merely as an aberrantly specialized side branch of the general shark stock, but Watson (1937) has demonstrated that they were remarkably primitive in retaining complete gill covers on the rear border of the upper and lower jaws as well as on both the upper and lower segments of the hyoid arch; thus the acanthodians verify the evidence from comparative anatomy that the inner or cartilaginous jaws of sharks and other early fishes are serially homologous with the branchial arches. And since the older acanthodians are so remarkably primitive in their general anatomy, it would be surprising if they did not retain at least some primitive features in their fins.

During the transition from bottom-living to free-swimming habits, the acanthodians, as actively moving predators, had evolved a complex functional shoulder-girdle for the support of their large pectoral spines. In the ventral view of *Climatius* (Watson 1937: 59, fig. 2) behind the gill chamber lies, on each side, a stout vertical bar (the "scapula") supporting the pectoral spine. Between the opposite scapulae was a pair of "posterior admedian plates," while in front of these came paired "ridged dermal bones," "anterior admedian," "anterior lateral," "cylindrical" and "median dermal bone," making no fewer than thirteen bones in the entire shoulder-girdle, which served as a sling and base between which the head and body were supported. Here again this pectoral girdle of the Acanthodii seems to us to have been derived by reduction of the extensive thoracic shield of the more primitive placoderms.

The possession of large spines has usually been thought to be a stigma of terminal specialization; but the physiologist Homer Smith (1939: 48, 49) has made the far-reaching suggestion that when the remote ancestors of the chordates first came up out of the ocean into the estuaries and inland waters, the salts and proteins of their tissue cells would by osmosis have caused an undue infiltration of fresh water; "so that by degrees the organism tended to pass from excessive hydration to edema and *in extremis* to swell to death . . ." He suggests that by certain changes in their renal and vascular systems they laid down a waterproof covering for the surface of the body and eliminated the excess water absorbed through the gills. Thus the first stages in the evolution of a skeleton were a chemical result of an adjustment to a new environment. A continuation of the same process led to the deposition of spikes and other forms of armor and still later these became variously adapted as locomotor organs, jaws, teeth, etc.

This highly ingenious hypothesis seems to be in complete accord with the palaeontological evidence, to which it affords an unexpected clue. As

noted above, Heintz (1931a) has demonstrated the progressive reduction of the pectoral spines among the Placodermi; these were very large and fixed in the acanthaspids, became highly movable and jointed in the Antiarchi, and were finally eliminated in the Arthrodira. The latter, however, retained a large shoulder-girdle consisting of bony plates; this served as a base for the head, which was fastened to it by a pair of peg-and-socket hinges; posteriorly a prominent crest on the underside of the top plate of the shoulder-girdle may have been attached posteriorly to the body, anteriorly to the head. Thus the girdle in arthrodires lay between the head and the rest of the body as it does in higher types and served as a fulcrum for the movement of the one upon the other. And in the later Arthrodira the pectoral girdle retained this function even after the pectoral spines had vanished.

In fact the history of the Arthrodira shows us not only that spines may be readily reduced and lost but that the thoracic shield may be reduced and slenderized to such a degree that in the later arthrodirans (Heintz 1931a: 237) we note the following functional and topographic correspondences:

ARTHRODIRAN PLATES	PRIMITIVE OSTEICHTHYAN PLATES
Anteroventrolaterals	Claviculae
Anterolaterals	Cleithra
Anterodorsolaterals	Supracleithra plus posttemporals
Externobasals	Epiotics (dermal)

In the pleuracanth sharks the emphasis rested upon a dorsal fin spine which had been moved forward on top of the head; and we suggest that this large spine, in addition to its protective value, may have served as a fulcrum for quick vertical undulations of the head.

Prominent spines on the anterior dorsal fin and conical projections on the pectoral fins would play an important part both in stabilizing the primitive fish and in protecting it against being devoured by others. In view of the wide systematic distribution of dorsal fin spines among the earlier Palaeozoic fishes and pre-fishes, it would not now be surprising if the presence of spines as well as of a heavy body armor of small plates, denticles, or scales were the primitive condition.

Although heavy spines and body armor are excellent for defence, they may become a hindrance to mobility and swiftness. Certain it is that in not a few evolutional series either the fin spines or the body armor or both underwent a reduction, often to the point of elimination. In the later eel-like acanthodians, for example, the spines became very slender and needle-like; in the squaloid sharks the spines show various stages of

reduction until in *Laemargus* they are eliminated, as they are in the modernized families of galeoids. The hybodonts and heterodonts, or Port Jackson sharks, are an exception in retaining spines on the dorsal fins. Moy-Thomas (1936), developing the work of Smith Woodward, has shown that the hybodonts may be derived from the spine-bearing ctenacanthids of the lower Carboniferous. He believes that these in turn were derived from spineless cladodonts of the upper Devonian. But at least one of the cladodonts (*Ctenacanthus clarki*) (FIGURE 1) had a well de-

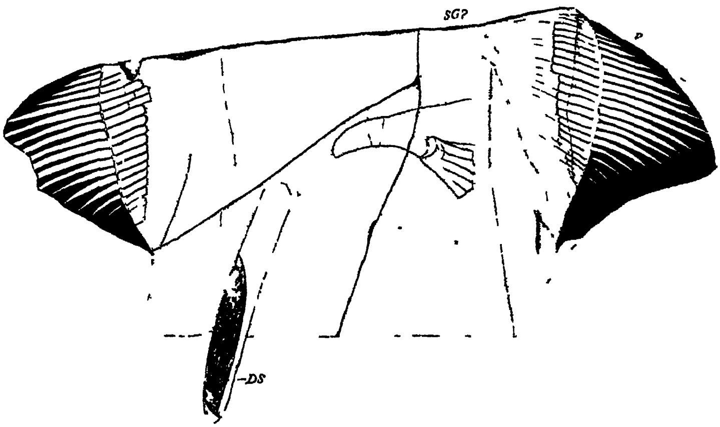

FIGURE 1. A dorsal fin spine in a cladodont shark. After Dean. × ⅛.

veloped dorsal spine (Dean 1909: 251). This makes it quite possible that the absence of this spine in *Cladoselache* may be secondary.

Between the dermal fin rays and their rod-like supports there is an intimate relation. This may be seen most readily in the skeleton of a skate but is also evident in the pleuracanths. Dean (1909: 245, 246) considered that the acanthodian fin spine (FIGURE 2) had arisen through the clustering of radials on the anterior border of the fin and that as the dermal denticles had coalesced into a spine the radials beneath them had retreated, after the analogy of the retreat of the Meckel's cartilage beneath the encrusting derm bones of the jaw in ganoids and teleosts. The anterior margins of median and paired fins are indeed usually strengthened by the coalescence of small elements, either by shagreen denticles coalesced into spines, as in acanthodians, or by scales uniting into lepidotrichs of varying stiffness, as in typical ganoids and teleosts. Dean

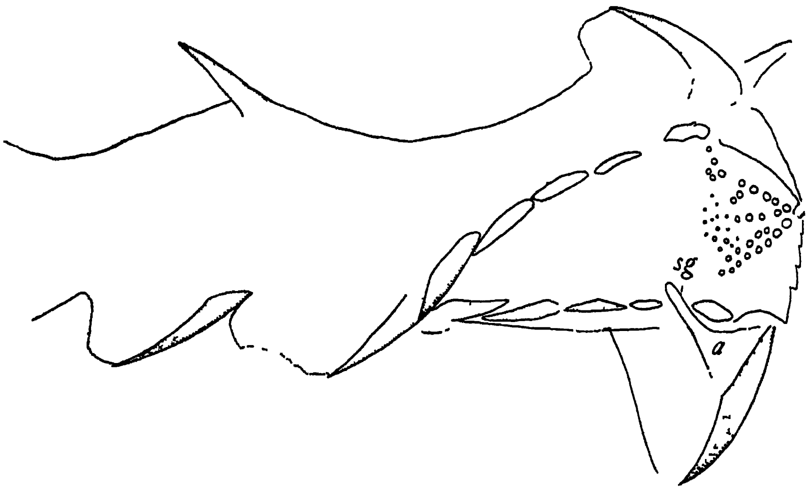

FIGURE 2. A primitive acanthodian (*Parexus falcatus*) with wide-based fin spines. After Dean, 1907.

(1909. 245) also cited evidence in support of his inference that the numerous long radial rods in the fins of *Cladoselache* (FIGURE 3), which extend

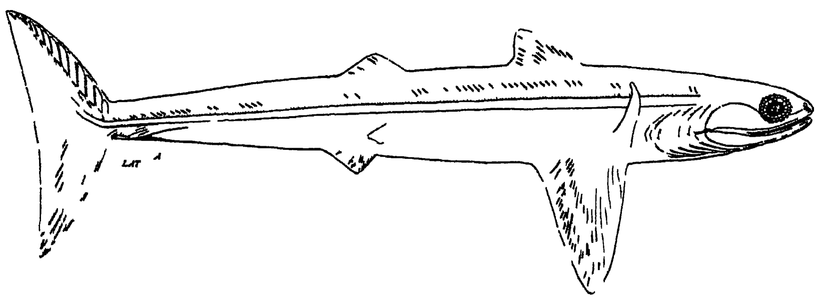

FIGURE 3. Dean's restoration of *Cladoselache*, illustrating supposedly primitive fin folds.

almost to the margins, were in a more primitive state than the few and very short radial rods that are barely indicated in certain of the well-spined, webbed fins of acanthodians. However, it has been shown by Heintz (1938: 23) that among the Arthrodira the reduction of the pectoral spines was accompanied by a development of the fin web and of its supporting rods (FIGURE 4).

With regard to the origin of paired fins in the shark group, we infer that in response to physiological requirements mineral matter was deposited successively in the integument after the manner of scale growth;

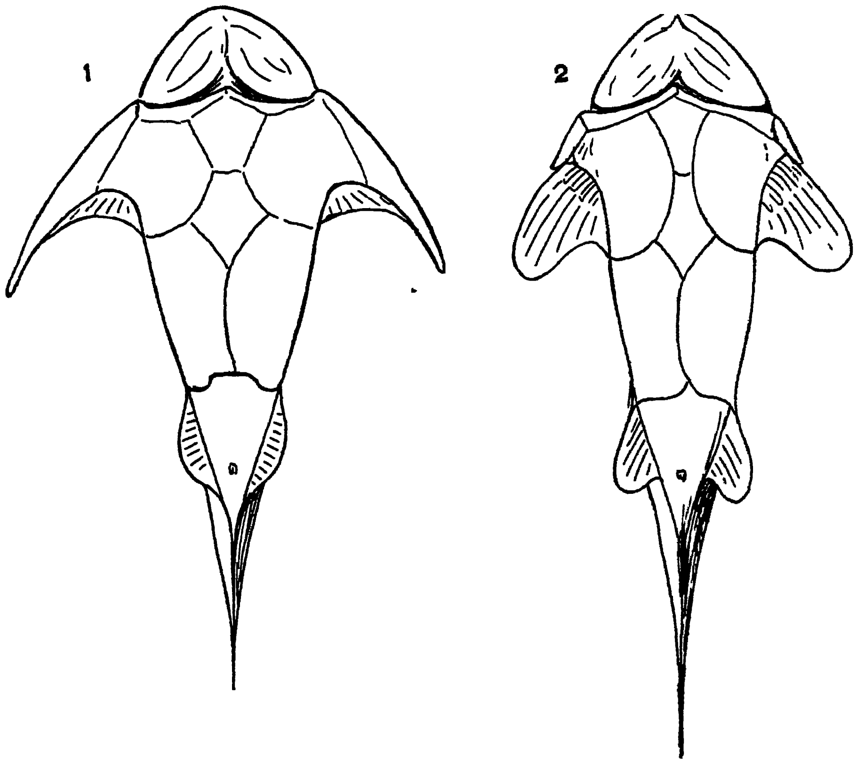

FIGURE 4. Suggested reduction of the pectoral spines and outgrowth of radials in coccosteids. Provisional reconstructions by Heintz.

these deposits were not evenly distributed but were concentrated at nodal points in a dorsal median row extending along the back and tail, and in converging lateral rows extending from the widest points behind the head to the anal region. If there were great crowding and concentration toward the anterior end of each node, spines were produced, as in acanthodians and as in the dorsal fins of ctenacanths, hybodonts, cestracionts, and squaloids. Less crowding at the base encouraged the spreading out of the inner layers of the supporting tissue into basals and radials. At any time retrogression of the spines would be favorable to extension of the basals and radials. Consequently we would be inclined to reconstruct the ancestral shark neither as a full-fledged acanthodian nor as a "primitive cladoselachian" as restored by Dean (1909: 244) but as much nearer to the *Ctenacanthus costellatus* type as restored by Moy-Thomas (1936: 764).

Whatever the exact form of the primitive shark may have been, we have much evidence that at an early date the metameric muscles seized hold of the bases of the nodal ridges and began to use them and their accompanying fin folds as movable keels and rudders. As the fin musculature began to attain its own individuality apart from its parent metameric mass, it spread radiately outward from the body toward the margin of the fins, carrying with it a set of stiffening endoskeletal rods which it had evoked between the opposing muscle masses either of the upper and lower faces of the paired fins or on the right and left sides of the median fins. From this viewpoint the extension of the radial rods to the tips of all the fins would be no more primitive in *Cladoselache* than it is in the pectoral fins of skates and rays. The large number and similarity to each other of the radial rods in *Cladoselache* used to be taken as a sign of primitiveness but it may rather be an example of what one of us (Gregory 1934) has called "secondary polyisomerism."

Most authors have assumed that an anteroposteriorly wide base, with little or no axillary incisure (as in Dean's "primitive cladoselachian"), is the primitive condition for the pectoral fins, but this is often not so in the Anaspida, Acanthaspida, Acanthodii, *Macropetalichthys;* the base is of variable width in the ctenacanthids and bradyodonts, and becomes very narrow in the pleuracanths and crossopterygians. And in *Cladoselache* itself the skeletal base of the pectoral fin narrows rapidly as we pass inward toward the pectoral girdle (Dean 1909: 229, fig. 28). Indeed in *Cladoselache acanthopterygius* (*op. cit.*, p. 228) the pectoral fin has a very narrow base.

Whether or not the pectoral fins themselves originally bore spines, it is at least highly probable that the presence of vertical keels on the mid-dorsal line would require lateral, horizontal projections along the ventral border, one pair immediately behind the head, another just in front of the second dorsal fin, as in the ctenacanths figured by Moy-Thomas. Similarly the presence of stout dorsal spines together with actively predatory habits would encourage the downward growth of the muscles and supporting rods of the ventral lobe of the tail, a development which reaches its culmination in *Cladoselache*. *Per contra*, the small size of these subcaudal rods in the heterocercal tail of the modernized sharks may well be a result of reduction associated perhaps with the partly bottom-feeding habits which are ascribed by E. G. White (1937) to the more primitive galeoids.

Likewise it has been widely assumed that the remote ancestral vertebrates were free-swimming, fusiform, or even eel-shaped, actively predaceous types; but the more recent evidence (Gregory 1928: 415)

suggests rather that they were dorsoventrally asymmetrical, somewhat depressed, partly benthic forms, feeding at first by ciliary ingestion of small floating particles and only gradually acquiring a fusiform body and predatory habits. According to this viewpoint, the active, free-swimming Anaspida would be the fish-like derivatives of the cephalaspid stock, while the acanthodians would be the earliest known predatory offshoots of the still unknown Silurian agnathic ancestors of the gnathostome stocks.

We may sum up the probable mode of origin of the pectoral girdle and fins as follows:

(1) Among the earlier known ostracoderms such as *Ateleaspis*, *Aceraspis*, *Thelodus*, the paired fins had begun to develop as horizontal ridges and the position of the future endoskeletal shoulder-girdle was already determined by the transverse septum behind the pericardium.

(2) In the Anaspida both the pectoral and the pelvic fins were part of a series of paired projections (spines) which may at first have enabled the fish to cling to the rocky bottom of fresh-water streams.

(3) From the earliest times these dermal projections were connected on the inner side with the metameric muscles of the flanks and they may at first have served partly as holdfasts, partly as creeping organs.

(4) The compound shoulder-girdle of later types arose when the endoskeletal basal pieces of the pectoral fin worked their way farther into the body and encountered the transverse septum behind the pericardium.

(5) The dermal plates of the shoulder-girdle represent dorsolaterally a remnant of the primitive thoracic exoskeleton, or carapace; ventrally the interclavicular and clavicular plates are survivors of the ventral portion of the same.

(6) The forward extension of the dermal plates of the pectoral girdle beneath the throat is already illustrated in the acanthodians.

(7) In the earliest known sharks the distal part of the pectoral fin was spreading in a fan-like way, increasing its mobility distally.

(8) According to Broili (1933: 426), a fan-like tribasic pectoral, with pieces corresponding to the pro-, meso-, and metapterygium of sharks, was already present in the upper Devonian *Macropetalichthys*, which may be related to the sharks on the one hand and to the Rhenanida on the other. Among the later acanthodians a long-spined pectoral fin of *Acanthodes* sp. described by Watson (1937: 113, 114) contained a fan-like skeleton of basal and radial elements arranged radially (*cf.* fig. 20, p. 317 below); this arrangement is reasonably interpreted as "tribasal, of general Elasmobranch character," with pro-, meso-, and metapterygia and short radials. Even among the cladodonts, *Denaea* of Pruvost (1922) had a fan-shaped pectoral with a narrow base, and though the propterygium

is said to be absent, the fin base is otherwise fundamentally like the tribasic pectoral of an embryo *Scyllium* figured by Moy-Thomas (1936: 770).

(9) We shall suggest below that a "tribasic pectoral" was also ancestral to the so-called archipterygial fin of the Crossopterygii and Dipnoi.

Regarding the skeletal bases of the pelvic fins, no trace of these structures has been found in the ostracoderms or antiarchs; even in the acanthodians Watson (1937: 122) states that "nothing is known of the cartilaginous skeleton of the pelvic fin." It might be supposed that this was due to poor preservation of the material but it may rather be an indication that the pelvic supports were not yet developed in these earliest gnathostomes. In the placoderm *Macropetalichthys*, however, according to Broili (1933: 427) there was an elongated, unjointed metapterygium which bore a series of jointed radials. In *Coccosteus* there was a pair of so-called "pelvic plates" and there may have been pelvic fins in certain other Arthrodira. The pelvic fins usually contrast with the pectorals in being considerably smaller and they are functionally connected with the tail more than with the head. There are seldom any dermal plates in the pelvic region of fishes that correspond with the dermal or outer plates of the shoulder-girdle.

The skeleton of the pelvic fins in the ctenacanth sharks (FIGURE 5), as

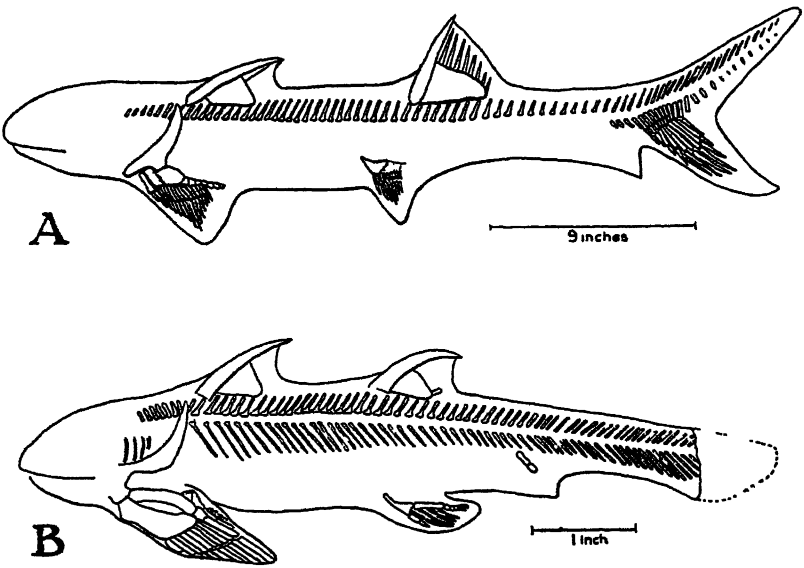

FIGURE 5. Primitive spiny sharks from the lower Carboniferous of Britain. After Moy-Thomas. A. *Ctenacanthus costellatus.* B. *Tristychius arcuatus.*

figured and restored by Moy-Thomas (1936: 776-778) as seen from below, consists of a fan-like arrangement of rods which converge toward the "pelvic girdle" (the opposite halves of which are well separated across the midline). Each half has an anterior process somewhat analogous with the scapula of the pectoral girdle but lying in the ventral body wall. The main part of the fin base is directed posterolaterally; it includes one large preaxial radial attached to a lateral process of the girdle and four smaller radials, all in a nearly horizontal plane. The mesial border of the fin is formed by an elongate "basipterygium," which gives rise posteriorly to an anteroposterior row of three squarish pieces; with the distal one of these articulates a rod-like piece on the medial side, and laterally to this, three small rectangular pieces. The posteriorly directed pieces suggest a metapterygial series. In *Ctenacanthus costellatus*, as figured by the same author (p.767), the paired pelvic plates are broadly triangular but with a concave inner border and inwardly curved anterior process; the radials project laterally. No metapterygium is indicated.

In the earlier elasmobranchs the pelvic fins and bases do not exhibit as wide a range of pattern as do the pectoral fins. For whereas the pectorals range from the "orthostichous" or long-based type seen in *Cladoselache* to the narrow-based, almost "mesorhachic" type of *Pleuracanthus*, the pelvics exhibit only minor modifications of the typical shark pattern, in which the radials converge toward the outer edge of the pelvic plate, except those which are attached to the metapterygium; this may or may not be extended and subdivided. (In this connection, see the data recorded by Goodrich (1909: 127-130, 183-186, 106-109). And since there are not wanting evidences of intermediate stages connecting the orthostichous and the mesorhachic types, it is important to remember that although they look very unlike each other, yet both extremes are known within the confines of one major group, the Elasmobranchii.

The Osteichthyes, or bony fishes in the wider sense, fall into two great assemblages: (1) the Actinopteri of Cope, including the palaeoniscoids, together with their highly diversified descendants, the sturgeons, the subholostean and holostean ganoids, the garpikes, the amioids and the teleosts; (2) the Choanata (in part) of Säve-Söderbergh (1934: 17), including the crossopterygians and dipnoans. When the earliest known representatives of these major groups first appeared in the Devonian they possessed in common many anatomical characters, especially in the skeleton and nervous system, yet they already differed widely in the construction of the endoskeleton of the paired fins. In the actinopterygians the earliest known pectoral fins (of the palaeoniscids) have the appearance of having been derived from a long-based ancestral type that

was essentially similar to that of the Devonian shark *Cladoselache* and they have indeed been so interpreted even in the latest work by E. I. White (1939). Sewertzoff in his "Evolution der Bauchflossen der Fische" (1934: 474) likewise takes the orthostichous pelvic fin of *Cladoselache* for the common source of the crossopterygian and actinopteran divergence. But as it is highly improbable on many other grounds that the Actinopteri were actually derived from the cladodonts, the resemblance in the paired fins of the two groups may be convergent. Moreover, Dr. E. I. White's diagram (1939: 56) showing "possible trends of development in the skeleton of the pectoral lobes in Actinopterygian fishes" by starting from a hypothetical cladodont-like ancestral stage ignores the abundant morphological evidence for a remote common ancestry between the actinopterygians and the crossopterygians. In such an ancestor the pectoral bases should be somewhat nearer to the rhipidistian type than to the cladodont type. Indeed it was long ago suggested by Smith Woodward (1891: xii, xxi-xxii; 1895: v, vi) that the general type of fin seen in *Cladoselache* and in the oldest Actinopteri was not altogether primitive, but had been derived by reduction of the central axis and increase of the lateral radials, and that since the crossopterygians attained their dominance earlier than did the actinopterygians, the former were probably on the whole the more primitive group.

It is true that few authors today would accept the dipnoan "archipterygial" type as the ultimate primitive; it seems highly probable that primitive paired fins have arisen by a combination of concrescence at the base and spreading distally. Nevertheless this is not inconsistent with Smith Woodward's view that in the oldest actinopteran forms (*Cheirolepis*, *Palaeoniscus*) the paired fins were undergoing a regression from an earlier, more rhipidistian stage in which the basal lobe was relatively more prominent. Goodrich (1909: 109) expresses a similar conclusion in the following words, "The orthostichous arrangement of the radials in the paired fins of the higher Teleostomes . . . is almost certainly secondary and due to the reduction of the axis."

Paired fins in the Crossopterygians

In the Choanata the paired fins are of that variable but highly characteristic narrow-based type named archipterygial, mesorachic, crossopterygial, and rhipidistial. This general type might well have been derived from that described above as occurring among the ctenacanthid sharks save for the objection that it is highly improbable that these two groups are at all nearly related. Evidently the general resemblances between the tribasic pectoral and the metapterygial pelvic fins of the shark

Tristychius (FIGURE 5) (Moy-Thomas 1936: 776) on one hand, and on the other the rhipidist *Tristichopterus* (Traquair 1876: pl. 32) are partly of independent derivation. Nevertheless, it will be seen that the generally more primitive conditions in the ctenacanthid sharks may well afford a real clue to the mode of origin of the paired fins of the rhipidists, dipnoans, and derived types.

The occurrence of tribasic, multiradial, fan-like pectoral fins in such widely unrelated forms as acanthodians (*Acanthodes*), placoderms (*Macropetalichthys*), sharks, and even *Polypterus* (Budgett 1903), further suggests that this morphologic pattern has been more or less independently evolved whenever the genetic and environmental factors gave it a favorable opportunity. From this point of view the occurrence of a wide-based pectoral with a very large number of radials, as in *Cladoselache* and in greater degree in ray-like forms, is not a primitive but a specialized condition. Accordingly we may return with greater confidence to the general ideas of Mollier (1884-1897), Budgett (1903), and others who tried to derive the so-called archipterygial pectoral from a multiradial shark type, even though the sharks themselves were not ancestral to the crossopterygians and dipnoans. Thus (FIGURES 6, 7) the rhipidistial fins of the Devonian crossopterygians and the orthostichous type of the palaeoniscoids may be regarded as divergent derivatives of a still undiscovered tribasic, multiradial ancestral teleostome fish.

In the pectoral fin of sharks the metapterygium is on the postaxial or dorsomedial border, and the propterygium on the preaxial or anteroventral border; the mesopterygium and its rods lie between them: the

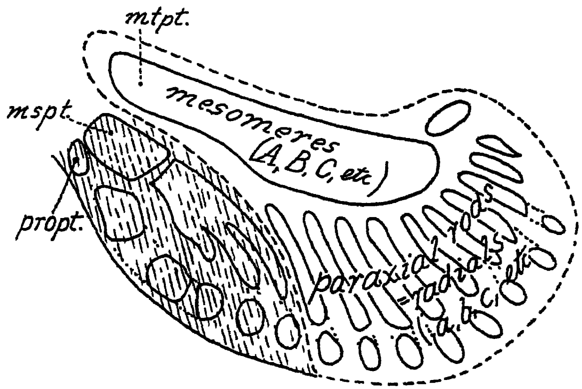

FIGURE 6. Diagram showing how a rhipidistial pectoral paddle might be derived from a tribasic type by loss (dark shading) of the pro- and mesopterygia and their radials, the subdivision of the metapterygium into the "mesomeral" axis, and the modification of some of the mesopterygial rods into radials attached to the mesomeral axis.

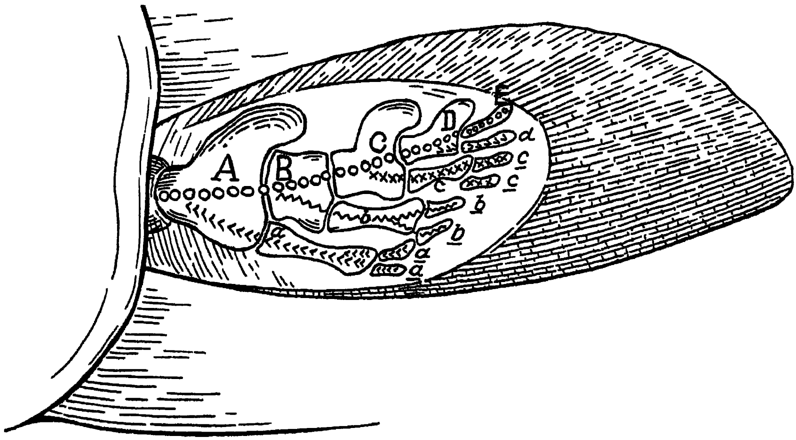

FIGURE 7. Diagram of the pectoral fin of *Eusthenopteron*.

mesopterygial rods are set at an angle to the metapterygial axis and might easily become associated with it. In modern sharks when the pectoral fins are bent outward and downward their upper borders tend to face outward. In higher ganoids and teleosts, on the other hand, the pectoral fin is folded back so that the originally preaxial border becomes dorsal, while the primitive upper or dorsal surface becomes parallel to and faces mesially toward the body.

In the upper Devonian *Eusthenopteron* and its allies, representing the rhipidistian Crossopterygii, the pectoral fin is no longer in the more nearly horizontal plane as it is in sharks but in a more vertical plane, with the preaxial margin on the lower edge and the jointed metapterygial axis nearer the dorsal margin. The fin as a whole is directed downward and backward from the glenoid articulation, which is placed at a relatively high level up from the ventral plane. The metapterygial axis is nearer to the dorsomedial border of the fin, which is shorter than the convex anteroventral border and composed of smaller fin rays. This is definitely shown in the type of *Sauripterus* (FIGURE 19) as well as in two of Bryant's *Eusthenopteron* and one of ours, also in the large specimen in the Albany, New York, Museum, figured by Hussakof (1912: fig. 2). Hence the preaxial rods, representing the rods of the mesopterygial series, are directed downward and backward away from the jointed metapterygial axis.

As long as the metapterygium and its distal pieces remained within or near to the body wall, as it did in *Cladoselache*, the pectoral fin could only undulate along its outer margin, essentially as in a skate. But by the

continued budding of the metapterygial axis the posterior tip of the fin became well freed from the body and an ovate-to-lanceolate leaf-like form was assumed. The narrowing base took on the movements of a wrist and the development of a ball-and-socket proximal joint permitted 8-shaped and lash-like movements. Meanwhile the mesopterygial radials, directed downward and backward from the metapterygial axis, served to strengthen the preaxial border of the fin.

In the pelvic fin of *Eusthenopteron* (FIGURE 10) the jointed metapterygial axis is nearer to the medial or cloacal side of the fin, which has smaller, more delicate rays and a short border, while the preaxial rods are directed toward the long convex anteroexternal border with its large dermal rays. But whereas the pectoral fins are directed obliquely backward and downward on the outer side of the body, the pelvic fins are placed more on the under side of the body and point obliquely backward and outward.

In *Osteolepis*, which is older (Lower Old Red Sandstone) and more primitive than *Eusthenopteron*, the pectoral and pelvic fins appear to be basically the same as those of the latter but the fleshy lobe covering the fin muscles is shorter, especially in the pelvic fin. Hence the skeleton of the pectoral fins of this primitive rhipidist, which is still very little known, should prove to be nearer to the tribasic shark type, while the pelvic fin must have had a shorter metapterygium. On the other hand, in the Triassic coelacanth *Laugia* (Stensiö 1932b: pl. 1) the fleshy lobe of the pectoral becomes a long and narrow stalk, the pelvic fins have moved forward and the pelvis (FIGURE 8) has become fastened beneath the pectorals and between the forks of the pectoral girdle in much the same manner as in the percomorph teleosts (Stensiö 1932b: pls. 2, 3). An elongated pectoral base is also seen in the recently discovered coelacanth

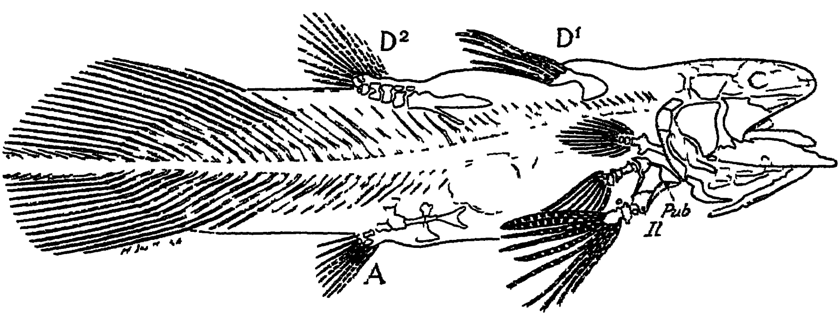

FIGURE 8. A highly specialized derivative of the primitive rhipidist stock. Restoration of a coelacanth (*Laugia groenlandica*) from the Triassic of East Greenland. Based on Stensiö's figures.

Latimeria (J. L. B. Smith 1940), a survivor of the coelacanth group which was dredged off the coast of East London, South Africa, in 1938. Stensiö (1921: 135; 1937: 50) has shown that though the coelacanths had already acquired their peculiar general stamp as early as upper Devonian times, yet some of them retained numerous detailed features which indicate that the group as a whole was a highly specialized derivative of the rhipidistian stem.

More recently Stensiö (1939) records the discovery of an early member of the holoptychiid family of the rhipidistians which foreshadows the coelacanths in certain important features. Thus it seems probable that some early branch of the rhipidistian group, the earliest members of which already show a wide range of differences in the construction of the skull and paired limbs, gave rise to the coelacanth group, in which a particular combination of features became fixed from the upper Devonian to the present time.

On the other hand, some more pliable branch of the rhipidistian stock seems to have given rise on the one hand to the Dipnoi and on the other to the tetrapods. In short, *Eusthenopteron* appears to be sufficiently primitive to be near to the basal rhipidist stock which gave rise to all three major branches, coelacanths, Dipnoi, tetrapods.

The climax of rhipidistial fin development was reached in the upper Devonian *Holoptychius;* here the pectoral fin is very long and narrow, bordered with long dermal rays, in allusion to which the group name Crossopterygia (tassel-fins) was invented. This same general type of fin was carried still further among the dipnoans until it finally degenerated into the highly flexible, tentacle-like paired fins of the African lungfish *Protopterus.*

We may sum up the previous discussion as follows:

(1) The evidence suggests that the earliest chordates (of which the ostracoderms were the diversified descendants) were somewhat dorso-ventrally compressed, clinging to a rocky bottom and sucking in small food by respiratory action of the throat.

(2) Median and paired fins were developed, especially as an aid in free-swimming, predaceous habits. A primitive sort of paired pectoral fins forming horizontal lappets or flaps was evolved among the Cephalaspidomorphi, while some of the active Anaspida acquired a converging row of fin spines leading from the pectoral to the pelvic fins.

(3) It seems probable that the dorsal and paired fins of the earliest gnathostomes were not continuous "fin folds" but nodally placed, compressed ridges strengthened anteriorly by a concentration of denticles or scales which often coalesced into fin spines.

(4) Among the earliest gnathostomes the metameric muscles early pushed their way into the base of the paired and median fin projections, producing there "basals," and "radials"; the surface of the ridge or fin was covered in the elasmobranchs with horny fibrillae (ceratotrichia), and in the bony fishes with radially disposed rows of bony ganoid scales (lepidotrichia); thus active undulation of the fins was effected by the combination of a firm but movable base and a flexible margin.

(5) The tribasic, multiradial type may have been developed more or less independently in the sharks, Stegoselachii (*Macropetalichthys*) and other groups as a result of the similar metameric axial musculature and similar integument. The pectoral fin was usually more fan-like than the pelvic, with narrower, finally more wrist-like base.

(6) The long-based "orthostichous" pectoral, beginning in *Cladoselache* and culminating in ray-like forms, has been derived from a more normal, short-based, tribasic type.

(7) The Osteichthyes, including the Actinopteri and the Crossopterygii, probably diverged from a common ancestral stock which had tribasic, multiradial pectorals; the pelvics were monobasic, orthostichous, and multiradial, sometimes with a tendency to prolong the metapterygial axis by budding.

(8) The *Eusthenopteron* type of pectoral is nearer to the primitive crossopterygian type than is the long tassel-like pectoral of *Holoptychius*, which presumably had postaxial as well as preaxial radials.

(9) There seems to be no good reason nowadays for regarding the "archipterygium" of Dipnoi as anything but an advanced derivative of a tribasic, multiradial fin in which the metapterygial axis, by budding, ultimately transformed the fin into a long flexible tentacle.

(10) Neither can we believe that the anatomy of the paired fins of the excessively specialized coelacanths can be a reliable guide to the early evolution of the tetrapod limbs. Consequently we return with greater confidence to the primitive rhipidistial type of girdles and limbs in our search for the pro-tetrapod stage.

PART II

A NEW RESTORATION OF THE SKELETON OF *EUSTHENOPTERON* (PISCES CROSSOPTERYGII, DEVONIAN, QUEBEC) WITH REMARKS ON THE ORIGIN OF THE TETRAPOD STEM

In continuation of our former studies on the evolution of the pectoral and pelvic paddles of rhipidistian fish type into the paired appendages of land-living vertebrates we undertook about two years ago to revise, and if possible to correct, previous restorations of the skeleton of *Eusthenopteron foordi* Whiteaves, which is from the upper Devonian, Escuminac formation, near Maguasha West, Quebec (Russell 1939). The prime basis for our studies was a collection of this fossil fish made for the American Museum of Natural History by Dr. Louis Hussakof in 1906 but this collection was eventually supplemented by several others from the same locality, namely, those of Dr. and Mrs. Horace Elmer Wood, 2nd, Dr. Thomas Barbour of the Museum of Comparative Zoology, Harvard University, Dr. Glenn L. Jepsen of Princeton University. The collections made for the Buffalo Society of Natural Sciences and described by William L. Bryant (1919) were represented by a fine series of photographs, which were kindly sent us by Dr. Bryant. The New York State Museum collection of *Eusthenopteron* at Albany, New York was studied there by the senior author through the courtesy of Director C. C. Adams. This collection includes the largest known and one of the most complete specimens of this fish, which was described by Hussakof in 1912. To all these persons and institutions we desire to express our most cordial thanks and appreciation, and especially to Mrs. Helen Ziska of the American Museum of Natural History, who, with infinite patience, has made and remade the drawings and successive restorations for the present paper.

Body-form

The skull of *Eusthenopteron* has been described by Whiteaves, Bryant, Stensiö, Jarvik, and as far as we have observed our material has presented nothing unusual. For the restoration of the skull we have had before us several fine specimens (Nos. 7647, 7564, 7674, 7849, 7584), as well as the literature of the subject. As noted below, the wide, relatively flat gulars and flat occipital roof contrast widely with the compressed skull and high supraoccipital keel of typical teleosts. Moreover, although the bodies are usually crushed flat, the similarity between

dorso-ventrally and laterally crushed specimens tends to confirm the view that the body immediately behind the skull was more or less oval or cylindrical in cross-section. This is consistent also with the relatively high position of the pectoral fins at their junction with the cleithra, as well as with the lowness of the dorsal blade of the latter.

The specimens at hand range in estimated total length from about 44 millimeters (PLATE 1, FIGURES 1, 2) to 863 millimeters (FIGURE 10). Most of them are crushed very flat and are variously mashed and distorted. The larger fishes are often bent into a U-shaped posture. A very few specimens are but little crushed and these of course are of great value. The relative proportions, from the smallest to the largest, are given in the accompanying table.

TABLE 1 GROWTH AND BODY PROPORTIONS FROM YOUNG TO OLD	A.M.N.H. 7687	Post-larval A.M.N.H. 7650	Bryant, Pl. 1, fig. 1	Young fish, M.C.Z. 6956	Whiteaves, Pl. V, fig. 5	Young fish, M.C.Z. 6954	Young fish, A.M.N.H. 7535	Young fish, M.C.Z. 6508	M.C.Z. 6957	M.C.Z. 5803	M.C.Z. 5817	Bryant's restoration (text fig. 1)	Albany Museum	New restoration
(1) Estimated total length (L) tip snout to mid-tip of tail	44	64	148	177	183	220	255	275	308	315	358	...	865	865
(2) Head length (H) tip snout to post. border operculum.	11	16	37	..	44	..	53	? 55	71	75	75	...	197	198
I. Head into total length $\left(\frac{L}{H}\right)$	4	4	4	...	4.1	...	4.8	? 5	4.3	4.2	4.8	3.8	4.4	4.4
(3) Max. body depth (d) in front of D2 (corrected for crushing)......	8	9	29	33	34	...	...	37	36	58	51	...	123?	123
II. Estimated max. body depth into total length $\left(\frac{L}{d}\right)$.........	5.5	7.1	5.1	5.4	5.4	...	7.3	7.4	8.5	5.4	7.1	6.2	7	7

From these data it would appear that the ratio $\frac{L}{H}$ in the larger specimens averages 4.5; in our restoration (FIGURE 10), which is based primarily on the very large Albany fish, this ratio is estimated as 4.4; in two very small specimens the head is relatively a little longer $\left(\frac{L}{H} = 4\right)$. In Bryant's restoration the head appears to be relatively longer $\left(\frac{L}{H} = 3.8\right)$ than would be warranted by the specimens noted in TABLE 1.

In the side view our restoration shows a somewhat *Polypterus*-like and very predatory fish, with the head a little shorter (relatively) than in Bryant's restoration and the body much less deep and compressed than in Whiteaves's restoration. The general proportions are thus not very different from those assigned to the British *Tristichopterus*, the nearest known relative of *Eusthenopteron*, in the restoration by Watson (Moy-Thomas 1939: 82); here head length into total length is about 4.2 and the body depth is about 1/7 the total length. The apparent depth of the body has usually been increased by crushing. Even after allowing as far as possible for this factor, the relation between the estimated depth of the body (d) a little in front of D 1, to its over-all length, averages about 7.1; that is, if we exclude the smaller specimens, in which this ratio varies from 5.1 to 5.4. In Bryant's restoration (text fig. 1) this ratio would be about 6.7; in our restoration it is 7; in Watson's restoration of *Tristichopterus* it is also about 7.

The new restoration (FIGURE 10), which is the first to attempt a complete, or nearly complete, representation of the postcranial skeleton, is a composite picture based primarily, as to size and proportions, on the very large Albany fish but with details supplied from many others. Although the Albany fish is bent into a U and its apparent body-depth greatly increased by crushing, it seems feasible to take the length along the curve of the vertebral column from the snout to the tip of the tail and then, by straightening out this line and measuring the distances of the fins from each end, to establish a preliminary basis for a restoration. The relative positions and sizes of the two dorsal fins (D^1, D^2), the pelvic and the anal fins, are given in many specimens and are fairly constant. The vertical spread of the huge caudal fin is well shown in the Albany and other specimens, as is also the long notochordal tip of the tail. The wide, nearly flat top of the skull is well preserved in a very large specimen figured by Whiteaves (1889: pl. 7) and in a smaller one (A. M. 7584) of

FIGURE 9 A young *Eusthenopteron* (A M N.H. 7835), showing *postmortem* distortion of backbone and body form Natural size A. Reverse. B Obverse

ours. Bryant also figures the head as flat or gently convex above in top view, widening from the blunt snout to the occiput, flattened below; thus much more like *Polypterus* than like typical teleosts with laterally compressed heads.

The widest part of the body was probably across the opercula (*cf.* No. 7584 A. M.). The highest point of the back was perhaps slightly in front of D1. The body cavity was long and not deep. The cross-section behind the abdominally placed pelvic fins became compressed toward the rear, culminating in the vertically extended caudal fin. The vertical spread of the triple caudal fin, 173 millimeters in the largest Albany fish, is about 1.4 times the estimated body depth. The very large size of the modified heterocercal or tristichopteral tail in *Eusthenopteron* is another point of resemblance to *Tristichopterus*.

Vertebral Column

The vertebral column of *Eusthenopteron* is still incompletely known. In most specimens the stout bony scales conceal the vertebrae and very often the latter, being somewhat weakly constructed, have left only obscure traces in the fossil. When the back is bent into a U-shape the delicate and incompletely coossified central pieces are usually found pushed toward the ventral surface and even when the body is not bent the mid-dorsal centra likewise sag toward the belly. Hence it has been only after repeated trials that we can tentatively assign the position of the column indicated in FIGURE 10. Evidently the horizontal level of the vertebral column at its junction with the occiput was relatively high; from this point the line of the centra sloped gently downward and backward to the posterior end of the body-cavity, thence curving gently upward to the basically heterocercal tail.

The best vertebral column known to us (FIGURE 11 and PLATES 2, 3) is in No. 7653 A.M.; a photograph of this was reproduced in a preliminary note on the vertebrae of *Eusthenopteron* by Gregory, Rockwell, and Evans in 1939. This large fish (FIGURE 11) shows that there was considerable regional differentiation in the vertebral column. Two of the cervical vertebrae of this fish show that in the well-ossified centra the notochordal lumen was still fairly large, but in the dorsal region it could hardly have been very large because parasagittal sections of certain dorsal vertebrae in No. 7676 (FIGURE 12) which are well beneath the outer surface of the rings are yet not deep enough to show the notochordal tunnel. In the mid-dorsal region of No. 7653 the centra as preserved appear as thin crescents; of these the right and left halves have been squeezed in such a way that the left half appears as a convex cres-

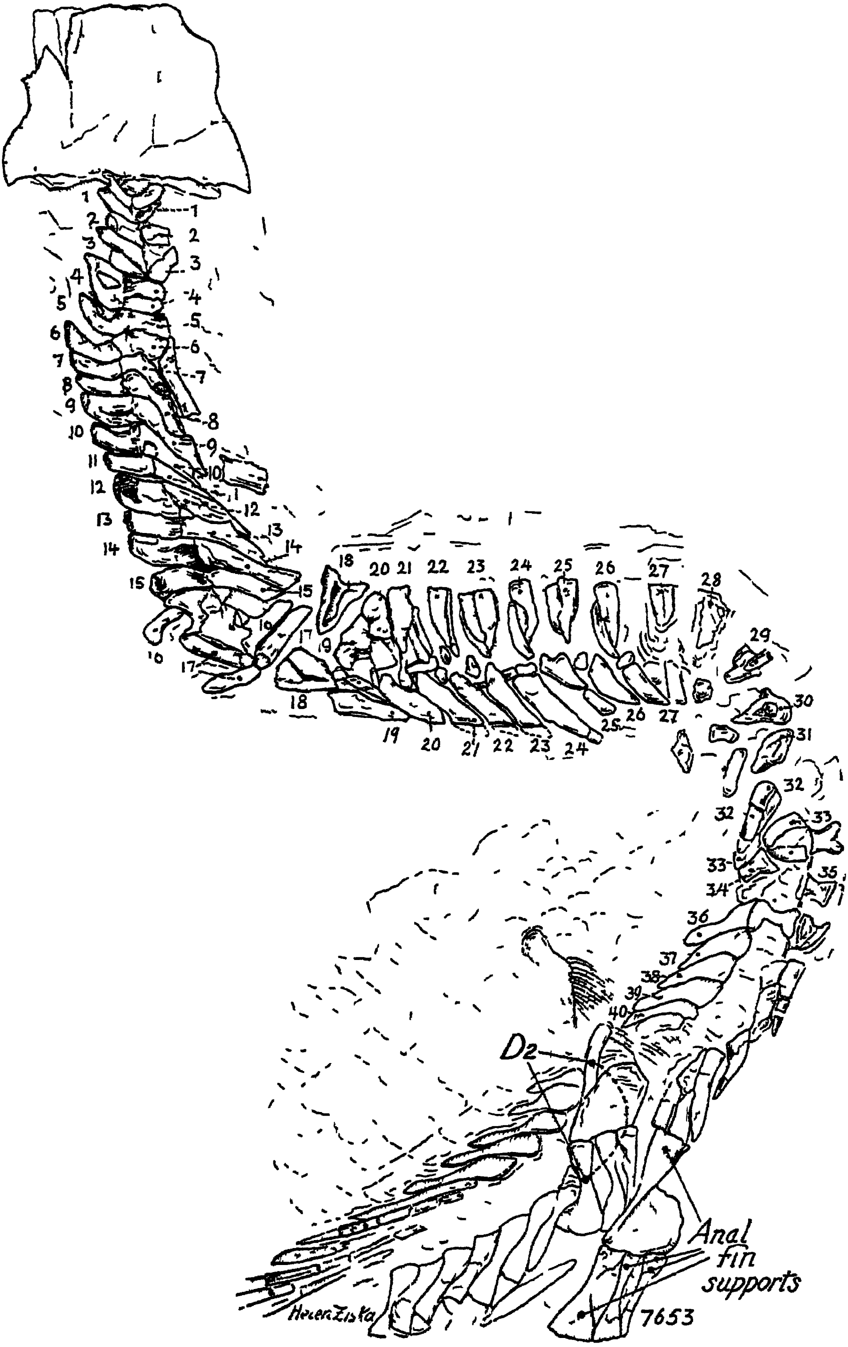

FIGURE 11. Vertebral column of *Eusthenopteron*. $\times \frac{1}{2}$.

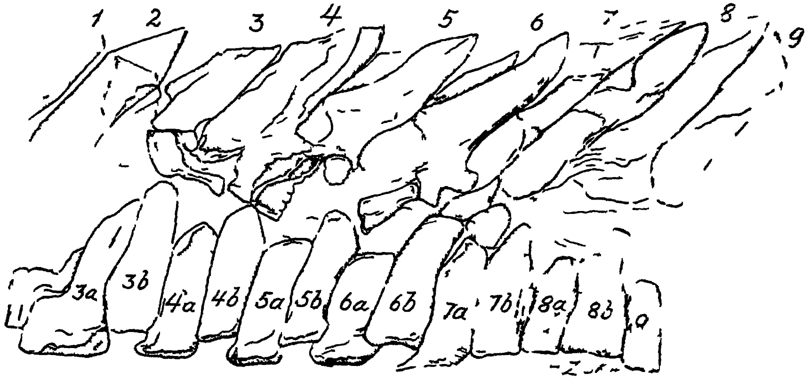

FIGURE 12. Vertebrae of *Eusthenopteron*, partly crushed.

cent and the right half as a concave one, we suspect however that the apparent thinness of these crescents is somewhat illusory and due to partial disappearance of the delicate bony tissue between the outer surfaces of the half-ring and the notochordal tunnel. Behind D¹ the centra appear to become separated by intervertebral spaces while immediately behind D² several centra become shorter vertically; in all the caudal region the centra are no longer ossified, the notochord and its sheath being represented by an empty tract between the neural and haemal arcualia.

No. 7676 A.M. (FIGURE 12) at first gives the impression that there are two complete centra to each neural arch but comparison both with younger specimens (M.C.Z. No. 6954, 6508) and with a large one (No. 5803) suggests that there was but one complete centrum (composed of right and left crescents) to each neural arch and that the appearance in No. 7676 is due to the thrusting of each left half-centrum in front of the right half-centrum. The lateral surface of the centrum when preserved bears irregular ridges or sometimes a lateral prominence suggesting a parapophysis. Nevertheless no trace of ribs was seen in any of the numerous fishes examined. The lower surface of each central crescent is flattened and somewhat shiny, as if it had been in contact with a smooth object, perhaps the dorsal surface of the lung-swimbladder.

In Bryant's text figure 8 (1919: 21), showing the end view of one of these half-central crescents, the thickest part of the crescent is on top, whereas our No. 7653 shows clearly that the bottoms of the crescents were flattened, the tops pointed. The vertical sulcus on the lateral face of each half-ring, which is so clearly shown in Bryant's plate 15, is at best obscurely shown in some of our specimens and definitely absent in

some of the small ones. Nevertheless it seems probable that these sulci, which presumably marked the course of metameric blood vessels, would appear, at least in larger specimens, more or less as we have indicated in the restoration.

The neural arches and spines immediately behind the occiput seem to be short and nearly vertical; they gradually lengthen and become more inclined backward to beneath D1, thence they become increasingly shorter, more slender, and still more inclined backward especially above the caudal notochord. The haemal spines, on the other hand, beginning at about the thirty-seventh vertebra, are at first slender; then there are two large ones for the support of the great basal piece of the anal fin; next they become fairly short; while above the anteroventral border of the tail they become quite stout and are articulated with about ten long rods, which in turn support the large dermal rays on the ventral moiety of the huge tripartite caudal fin. No epineural or interneural rods have been detected in any of the many specimens examined.

In No. 7676 some of the neural arches (FIGURE 12) have concave anterior (rostral) surfaces; each of these seems to have received the convex posterior (caudal) surface of the arch in front of it. Several of these spines look as if they were bifid dorsally. This specimen also indicates the presence of low anterior zygapophysial processes and articulations but these are but poorly if at all shown in other specimens; a sharp, backwardly directed zygapophysial process from near the base of the neural arch lies well below the level of the anterior zygapophysis.

Behind and beneath each neural arch was a pair of (right and left) bony nodules which may have represented the pleurocentra of labyrinthodonts. In one case (No. 7676) it appears as if the lower ends of the neurocentra were separate from the neural arch but this is very probably due to fracture. Above the pleurocentra in No. 7676 there was a depression which may mark the place of exit of a spinal nerve. In brief, the vertebrae of *Eusthenopteron* were notochordal and temnospondylous. This condition of the vertebrae has already been noted by Watson and Day (1916) in *Glyptolepis*.

In the middle part of the column the intervertebral spaces may have been more or less pronounced in large specimens but in small ones the successive block-like centra appear to be separated but little if at all from each other. The total number of vertebral segments from the occiput to the first ray of the epichordal part of the tail was about fifty-seven; of these the thirty-ninth was connected above with the "handle" of the basal piece of D2, while the fortieth and forty-first bore the haemal rods for the anal fin.

Median Fins

Of the two dorsal fins D1 is more delicate than D2. It lies at or slightly behind the summit of the long and slight dorsal rise. In the original of Bryant's plate 1, figure 2, there was a very large and long flat rod which Bryant took to be the basal piece of the first dorsal fin (D1). Although the basal support of D1 is very seldom shown in our material it is very beautifully preserved in No. 37-32 H.E.W. (A.M. 8095). This is a thick three-sided bone (FIGURE 13) with well-rounded corners, of which the smooth upper corner bears the three small rods in the muscular lobe of the fin. Indications of this large rounded bone are found in several other specimens. In this specimen it is completely free from the small neural spines beneath it and in no case known to us does it seem to be connected below with the neural spines or centra.

In view of the unquestionable character of this bone in our specimen we are led to doubt the correctness of Moy-Thomas's revision of Whiteaves's original restoration in so far as the former (apparently on the basis of Bryant's text, p. 21 and pl. 1) places a rod-like bone beneath D1 and connects it below with one of the neural arches. A possible alternative identification of the long rod-like bone in Bryant's plate 1 may be that it is a badly displaced supracleithrum and that its supposed "zygapophysis" is really the process for articulation with the cleithrum (*cf.* Bryant's text fig. 7).

The irregular plaque that lies ventral to the column in the same specimen is wholly unlike our known pelvic bone. The rounded bony basal of D1 seems surprisingly large in view of the smallness and slenderness of the three rods in the basal fleshy lobe of the fin above it. Possibly this large basal piece may have been connected by fascia or ligament with the larger but more delicate base of D2. Both may, as suggested by Whiteaves and Watson, have been derived through the concentration and concrescence of earlier interneural pieces. However, the bones of both dorsal fins differ widely from the interneurals and pterygiophores of typical fishes.

Apparently embedded amidst the dermal rays of D1 in this specimen (H.E.W. 37-32) is a large flat, bony strip with a well-rimmed anterior margin, all of uncertain significance. Such a structure has not been seen by us elsewhere. Possibly it may represent a fusion of some of the dermal rays (lepidotrichia) of the fin.

Beneath and behind D1 in several specimens there was a bony dermal plate ridged apparently in the mid-dorsal line and somewhat analogous to the ridged scutes on the skin of a sturgeon. This bony plate looks as

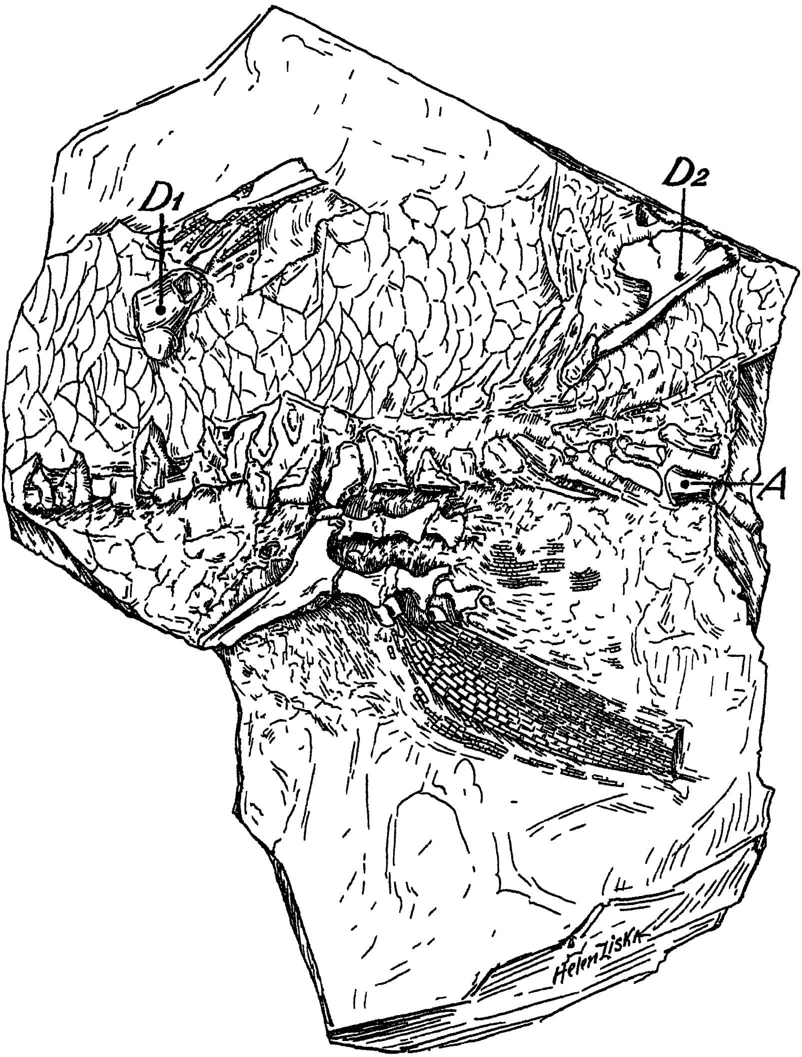

FIGURE 13. Pelvic region with first and second dorsal fins of a large specimen of *Eusthenopteron* collected by H. E. Wood, 2nd. Slightly less than 2/3 natural size.

if it were made of the same material which forms the base of the large scales. Bryant speaks of such plates as being present beneath and behind D1 and D2 but we cannot certify their presence behind D2.

The basal piece of the second dorsal fin (D2) is widely different from that of D1. In small specimens it is usually incompletely shown but in the very large specimens H.E.W. No. 30-11 (A.M. 8096) is very well

preserved and is exactly like the large one figured by Whiteaves (1889: 79). Its upper or dorsal part consists of a large ovoid area bearing on its distal edge a row of three facets for three distal rods in the muscular lobe of the fin. At the posterior boundary of this ovoid plate is a prominent and straight stiffening ridge, which is continued downward into the lower part of the bone, which consists of a curved rod. The lower end of this rod articulates with the dorsal extremity of a neural arch. This contact can be clearly seen in H.E.W. 37-32 (A.M. 8095) and is less clearly shown in several other specimens. Hence we are compelled to doubt Bryant's view (p. 2) with regard to the derivation of the basal supports of D1, D2, which was that they represent modified neural spines. We think rather that they are probably analogous with epi- or interneurals of typical fishes and that they have arisen between the fascia of axially derived fin muscles and have later grown downward so that in D2 a ventral apophysis of the basal piece has gained contact with one of the neural arches. A somewhat analogous but more advanced stage is seen in the heterodont sharks, in which the basal supports of the two dorsal fins have sunk down and gained a base even on the central part of the column.

The three radial pieces that support the muscular or lobate part of D2 are much larger than their analogues in D1. The rear one is much the largest of the three, the middle is intermediate, the first, slender. The distal end of the rear rod is expanded rostrocaudally and is somewhat analogous with an expanded hypural bone in teleosts. These radials evidently moved as a set, over relatively small lateral and rostrocaudal arcs, in imparting larger undulatory movements to the stout lepidotrichia of the fin.

The anal fin (FIGURE 10) closely resembled its partner D2, except that the proximal end of its large basal piece was much wider (anteroposteriorly) and straighter than the curved handle of the basal piece of D2. Moreover the wider proximal end of this bone was connected with two fairly large haemal spines, as is clearly shown in Nos. H.E.W. 37-32 and in A.M. 7653. This point is important when one is trying to distinguish between the dorsal and the ventral borders of imperfectly preserved and crushed specimens. In Whiteaves's restoration the differences in form between the basal pieces of D2 and the anal fin are not well shown. The three radial pieces in the muscular lobe of the anal fin are drawn as if they closely resembled those of D2. However, there can be now no question that the large basal piece of the anal fin lay below the row of haemal spines and thus corresponds in derivation to the basal piece of D2, whereas according to Bryant's interpretation the basal piece of D2 be-

longed to the neural arch series while that of the anal fin belonged to the interhaemal set.

The very large triple caudal fin (PLATE 1, FIGURE 3) is externally homocercal, or, more exactly, tripartite, and internally heterocercal. The epichordal neural spines are delicate and widely overlapping, the haemal rods much stouter. To the latter are attached the long radial rods of the hypochordal lobe. None of the haemal rods is expanded into an hypural fan.

Girdles and Paired Fins

The pectoral girdle has been well described and figured by earlier authors, especially in its lateral aspect. However, apart from Bryant's figure (pl. 14, fig. 1) little has been published upon the medial aspect of the pectoral girdle, which in our specimens displays several well marked features.

Clavicula and cleithrum are so closely united to form a large, more or less crescentic bone that we have seen little if any evidence for locating the suture in the position indicated by Bryant (text fig. 7). Indeed several young specimens suggest that the clavicle has an ascending branch which overlaps the middle part of the anterior border of the cleithrum. The difficulty here is that this possible ascending bar of the clavicle may represent part of the gular system. In several flatly crushed specimens (especially H.E.W. 30-32 [A.M. 8097] and M.C.Z. 5816-17) there is a sharp horizontal line (FIGURE 14) somewhat resembling a suture at the base of the ascending blade of the cleithrum. Close

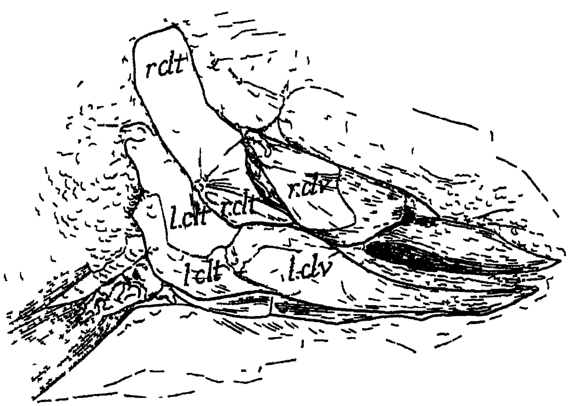

FIGURE 14. Crushed pectoral girdle of small *Eusthenopteron*. × 1.

examination indicates that this is a crack, not a suture. On the medial surface of the ascending blade of the cleithrum there is a convex raised area, forming a large acute triangle with its apex near the top of the anterior or opercular border of the blade and its base horizontal, in front of the glenoid region of the pectoral paddle. Opposing this dorsal triangle is a conspicuous smaller ventral triangle on the ventral half of the claviculo-cleithrum. The ventral triangle surrounds a sharply depressed area of unknown function. It might be supposed at first that into this depressed triangular area fitted the lateral face of the scapulo-coracoid, but not one of our specimens affords direct evidence as to the latter, which seems to be well shown only in Bryant's specimen (pl. 14, fig. 1). We suspect that the scapulo-coracoid was small and did not extend far in front of its glenoid portion; the latter in turn was well behind the depressed triangle. On the whole it seems probable that this triangular area served for the origin of some of the strong muscles on the medial surface of the pectoral fin.

No evidence of an interclavicle was noted.

The pectoral paddle of *Eusthenopteron* (FIGURES 7, 10) has been described by many authors, including Whiteaves (1889), Traquair (1890), A. S. Woodward (1898), Goodrich (1902), Bryant (1919), Holmgren (1933). Its muscular lobe and strong lepidotrichia were supported by a series of four or possibly five mesomeres, each of which bore a lateral rod or radial in a diminishing series. For convenience we have designated the mesomeres as A, B, C, D, E, and the radials as a, b, c, d. Several well preserved specimens show the radials, a, b, c, d, along the preaxial or anteroventral border, which in turn is indicated by the larger size of the lepidotrichia and by the convexity of the margin of the fin. The line of the mesomeres is much nearer to the postaxial or dorsomedial border of the fin. Mesomeres, A, C, and D, each bore on its postaxial, distal corner a large distally directed process that suggests the entocondylar process of the humerus of the early tetrapods.

The pelvic paddle and pelvic bone of *Eusthenopteron* were figured by Goodrich (1902: pl. 16) but since then but little has been discovered about them. For a long time we searched in vain for reliable evidence regarding the pelvis itself. Gradually it became clear that the bones designated by Bryant in the legend of his plate 13 as the "supports of the ventral fins" were really the juxtaposed large basal pieces of the second dorsal and anal fins (FIGURE 15). In the large Albany fish the pelvic bones were obscure and in many small specimens they were indicated merely by vague marks. At last, however, Dr. H. E. Wood, 2nd, supplied the pelvic region of a large fish (H.E.W. 37-32), which upon being

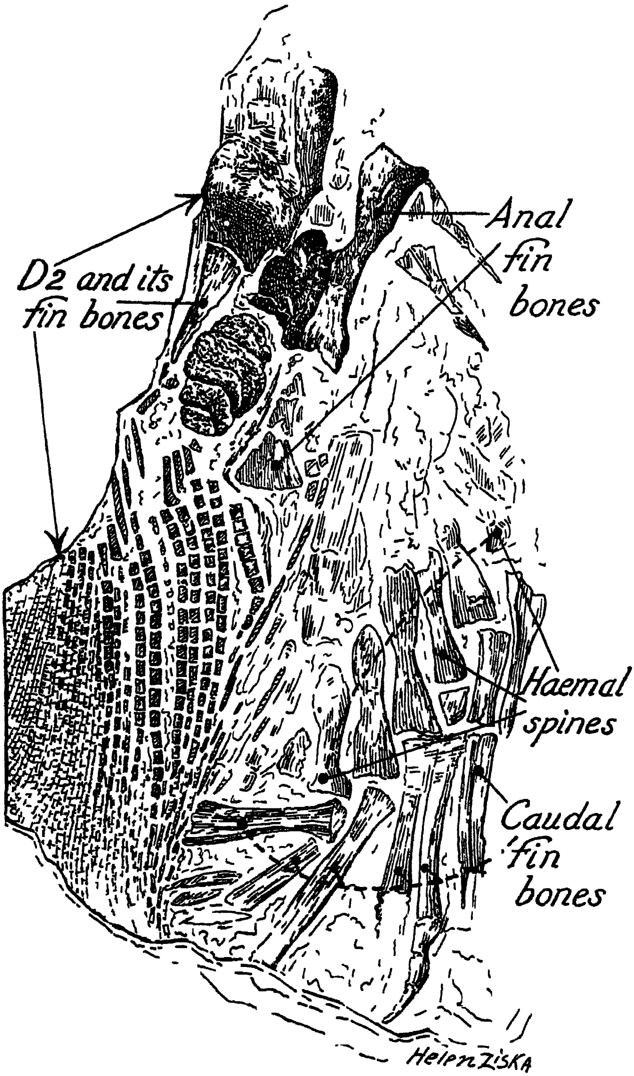

FIGURE 15. Bryant's specimen of *Eusthenopteron*, showing supposed pelvic bones, here interpreted as basal pieces of the second dorsal and anal fins. The anal fin support has been crushed upward. × ¹⁄₁.

exposed (FIGURE 13) revealed an almost perfect left half of the pelvis, a nearly perfect left pelvic paddle and parts of the right one, together with the best known basal piece of D1 and several valuable items as to the neural and haemal arches. The pelvic girdles and paddles had, however, been pushed up against the vertebral column. This probably

accounts for the sharp downward dip of the long anterior or pubic projection of the pelvic rod. The acetabulum faced almost wholly backward and there was thus no posterior ischial prolongation. Above the acetabulum was a prominent dorsoposteriorly directed process which we are provisionally calling the iliac process. On the medial side this process was in close contact with a similar-appearing surface of the opposite side. If this contact is due to crushing there is no apparent difficulty about calling the process itself an iliac process but if the contact in question is a natural one it would perhaps represent a sort of ischial symphysis. As this would bring the opposite acetabula very close to the midline, it seems improbable to us and we are therefore assuming that the process in question is really on the dorsolateral side of each pelvic bone. The great extension of the pubo-ischiadic rod in front of the acetabulum implies that the muscles protracting the pelvic paddles were strongly developed and that the latter were used as in recent fishes for checking forward locomotion.

The pelvic paddle (FIGURES 10, 13) is much like the pectoral but perhaps a fourth smaller. Its axis includes three visible mesomeres (A, B, C) with their attached radials (a, b, c). The latter, as in the pectoral paddles, are nearer the convex preaxial border, while the line of the mesomeres lies nearer the medial or postaxial border. By virtue of their position nearly beneath the body the pelvic paddles were probably directed backward in a nearly horizontal plane; like the pectoral paddles they could readily be turned downward and outward or backward and inward, and both pectoral and pelvic paddles were able to rotate, twist and bend in various directions.

Summary of Main Skeletal Characters

The main proportions are: head into total length, 4.4; body height (in front of second dorsal) into total length, 7; body height into vertical spread of tail, 1.4. In general the fish had a blunt snout, nearly flat occipital roof and flat gular region; immediately behind the opercula the body was rounded, not deep, in cross-section, gradually becoming compressed caudalward.

Vertebral column showing considerable regional differentiation. Vertebral segments represented by about 57 neural spines. Vertebrae notochordal and temnospondylous, with crescent-like half centra (intercentra) and nodular pleurocentra, intervertebral spaces marked in mid-dorsal region, centra fading away behind the anal fin. No interneurals, no bony ribs. Neural arches in anterior cervical region rela-

tively short, becoming longer and more inclined caudalward, with incipient anterior zygapophyses, especially in dorsal region.

Two dorsal fins, both paddle-like, with prominent fleshy lobes containing three radial rods; basal piece of D1 large, roundly triangular, not connected below with neural spines; basal piece of D2 expanded ovoid, with forwardly curved slender inferior process, the latter connected below with small neural spine; basal piece of paddle-like anal fin with wide proximal end connected with two strong haemal spines; about 10 or 11 caudal haemal spines, each bearing distally a rod-like radial, to which in turn were fastened strong and long dermal rays (lepidotrichia) of the huge caudal fin; the latter internally heterocercal, externally tripartite, with a long notochordal wisp.

Clavicula-cleithrum closely united, scapula-coracoid small and rarely preserved; medial surface of clavicula-cleithrum bearing a conspicuous acutely-triangular depressed area, possibly for attachment of the scapulo-coracoid.

Pelvic rod narrow, elongate, with pointed pubic tip, caudally placed acetabulum and no postacetabular (ischial) extension; a low dorsoposteriorly directed process, the probable homologue of the ilium.

Pectoral and pelvic paddles essentially similar, of so-called abbreviate archipterygial type, with four or three mesomeres and as many parameres or radials, the latter being near the convex anterior or preaxial border, the mesomeres nearer the postaxial border.

The Living *Eusthenopteron*

If we could see a living *Eusthenopteron* in a large aquarium tank it would probably remind us of various ganoids, dipnoans, and even of certain specialized teleosts. On the whole it would most nearly resemble the living *Polypterus* in the general form of the head, rather flattened above, with a blunt snout and flat throat. In slow movements its paddle-like second dorsal and anal fins would be swaying from side to side in unison; in turning and backing the huge caudal would sway with rippling borders. Especially when the fish was on the bottom the paired paddles could be thrust outward and moved almost like legs, as may be seen in the existing Australian lungfish. In the sudden dash after the prey the strong axial muscles would throw the whole column into large curves and the vigorous median fins would paddle furiously. In sudden stopping or "freezing" the paired fins would be thrust outward and all the fins would be cupped forward. When quite near the prey the lower jaw and throat would be sharply depressed and the front part of the

head raised. All this would tend to form a yawning chasm into which the victim would be sucked.

Derivation and Relationships

As compared with later groups of osteichythyan fishes, the order Rhipidistii, to which *Eusthenopteron* belongs, is conspicuous for the comparatively narrow range of its structural diversity. In other words, even such extreme forms as *Holoptychius* and *Eusthenopteron* inherit many basic features in common. We can find nothing to prevent them both from being derived from *Osteolepis* of the middle Devonian. This genus, to judge by analogy with the known history of the palaeoniscoid fishes, is far more primitive than any of the other typical genera, especially in the following characters:

(1) Its much smaller size and far less specialized general appearance.

(2) Its scales are of the small and thick primitive rhombic type, coated with a smooth shiny layer of cosmine, without the elaborate surface ornamentation of the *Eusthenopteron* and *Holoptychius* scales.

(3) Its pectoral and pelvic fins are relatively small, with short fleshy lobes, but little advanced toward either the narrow fringe-finned *Holoptychius* or the broad *Eusthenopteron* types.

(4) Its tail is simply heterocercal, the dermal rays not produced to form a large triple tail.

(5) The two dorsal and anal fins are in an early stage of differentiation and there is no evidence that they were supported by any such highly specialized structures as are found in *Eusthenopteron*.

(6) The vertebrae of *Osteolepis* in so far as they are known in the closely allied *Glyptolepis* are temnospondylous (Watson and Day, 1916) and could readily give rise to the more differentiated conditions recorded above in *Eusthenopteron*.

(7) In respect to skull structure the elaborate studies of Pander, Watson, Säve-Söderberg and others on the skull of *Osteolepis* and of Bryant and others on the skull of *Eusthenopteron* demonstrate a relatively close relationship between these genera and assuredly in respect to its dentition there can be no question that *Osteolepis* is the more primitive.

The derivation of *Eusthenopteron* from *Osteolepis* is further proved by the existence of another upper Devonian genus, *Tristichopterus*, which is structurally intermediate between the two genera and is in all probability a survivor of the actual ancestor of *Eusthenopteron*.

Eusthenopteron is also closely related to *Megalichthys* of the Carbonif-

erous and Permian periods. The Texas representative of this genus ("*Ectosteorhachis*" Cope) has a wide, almost batrachoid head (whence the name *Parabatrachus* Owen) but its endocranium, described by Romer (1937) is essentially like that of *Eusthenopteron*. The same is true of its inner and outer jaws, its dentition, scalation, ring-vertebrae and paired appendages.

In another direction *Eusthenopteron* or some nearly allied genus affords an excellent structural ancestor to the coelacanths. Even *Latimeria*, the recently discovered survivor of the coelacanths, may safely be considered to be a directly specialized or "orthogenetic" derivative of the *Eusthenopteron* stem. Indeed, Dr. Bobb Schaeffer, who has recently completed a most thorough point-by-point comparison of the various coelacanth skeletons, has come to the same conclusion.

A little over two years ago when the newly discovered *Latimeria* was being discussed and figured in the newspapers and illustrated weeklies, the idea was expressed that a close study of this form might be expected to yield some evidence relating to the transitional stages from fishes to land-living vertebrates. But it has long been realized by students of the subject that the coelacanths became specialized in a direction far from that which led to the tetrapods. The coelacanths have indeed emphasized the limb-like features of their dorsal and anal fins and greatly enlarged the dermal rays of the tail, whereas the piscine ancestors of the tetrapods must have diminished and finally eliminated the dorsal, anal and caudal fins.

Here it might be objected that since *Eusthenopteron* had already become specialized in the direction of the coelacanths, in so far as it had developed an early stage of the limb-like form of the dorsal and anal fins and had enlarged its caudal fin, it was by reason of these specializations automatically excluded from ancestry to the tetrapods. It must be admitted that this sort of reasoning is widely prevalent among systematists in many fields, who have tacitly assumed that Dollo's law of the irreversibility of evolution, besides meaning that an organ once lost can never be regained, has also been shown to imply that a specialization once acquired can never be lost. Hence the presence of any marked specialization is often taken as justifying some such frequently read remark as that "the form A is far too specialized to give rise to the group B." But our experience leads us to the conclusion that such an extension of Dollo's law is an assumption that is often contradicted by the evidence. Of course there are many cases in which when a particular path leading to a high degree of specialization is once entered, it is followed to an extreme from which there is no turning backward. But

there are many other cases, abundantly well testified, in which even fairly high specializations have become retrogressive and finally eliminated. Here may be cited the reduction and elimination of the lower tusk in the ancestors of the elephants, the loss of the upper tusks in the manatee, the remodelling of the specialized arboreal foot of the primitive phalangers into the differently specialized feet of the wombats and *Diprotodon* (Huxley, Dollo, Bensley). Among invertebrates we may cite the reduction and nearly complete elimination of already specialized shells in certain lines of cephalopods and gasteropods.

That one system of specializations after a period of advance has receded and finally disappeared, while another system became dominant, seems indeed to be a far more frequent method of evolution than has often been appreciated. It is well illustrated in Dollo's classic paper on "La phylogenie des Dipneustes" (1895), the main results of which have been accepted and confirmed by later authors. Dollo showed that while the oldest known dipnoan, the Devonian genus *Dipterus*, was already specialized in the marked emphasis of the dermal rays of its dorsal, anal, and caudal fins, and in the distinction of these fins from each other, its descendants gradually reduced the differences between the several median fins, merged them into a continuous fin fold and reduced, and in some forms almost eliminated entirely, the once prominent scales and dermal rays. In brief, the fins which were so conspicuously specialized in the ancestral *Dipterus* were nearly eliminated in some of its descendants.

So too we may well assume that in the typical rhipidistians the fins that were posterior to the paired fins were perhaps of even greater importance than the paired fins themselves, but when these already well-lunged creatures began to be stranded in drying-up pools, the incidence of selection upon mutation was reversed and the paired fins became stronger and more complex, while the median fins declined even to the point of eventual disappearance.

Strong but indirect evidence for this conclusion results from the extremely detailed comparisons of the structure of the skull of rhipidistians on the one hand with that of the earliest labyrinthodonts on the other, by Watson, Säve-Söderbergh, Romer, Westoll, and others; all of which points at least to the close relation of the tetrapod with the rhipidistian stem.

The one conspicuous specialization which in the opinion of most authors excludes all the known rhipidistians from direct ancestry to the tetrapods is the presence on the top of their skulls of a transverse crease immediately behind the so-called frontals, which permitted the anterior part of the head to be tilted upward when the jaws were opened. Even

in the new edition of Parker and Haswell, volume 2, which has been so excellently revised by C. Forster Cooper, we read that ". . . in all Crossopterygii there is a line running transversely across the skull between the frontal and parietal bones which divides it into two portions. This feature alone would prevent any known crossopterygian from being regarded as ancestral either to the dipnoan or tetrapod lines."

To the contrary, as it seems to us, in view of the great number of detailed agreements in structure between *Eusthenopteron* and the primitive labyrinthodonts, the evidence clearly indicates that during the period of profound reorganization, from water-living to land-living habits, the fore part of the skull became closely appressed to the rear part and gradually lost its mobility as the two morphologically distinct parts became integrated into a single syncranium.

In short the collective researches of the past three decades have, in our judgment, greatly strengthened the evidence for the derivation of at least the labyrinthodont tetrapods from the rhipidist stem, and possibly even from a close relative of *Eusthenopteron*.

PART III

ON THE TRANSFORMATION OF PECTORAL AND PELVIC PADDLES OF *EUSTHENOPTERON* TYPE INTO PENTADACTYLATE LIMBS

Some recent fishes can use their paired fins as limbs. *Periophthalmus*, the mud-skipper, a highly specialized teleost, is such a fish. However, it uses only its pectoral fins and these in conjunction with a springing action of the tail.

Polypterus, the well-known African form, also uses its pectoral fins to assist it through the mud, as well as for swimming.

Ceratodus, the Australian lung-fish, uses its pectoral and pelvic fins to help propel it on muddy bottoms, although they are incapable of supporting the animal. *Eusthenopteron* also presumably made use of its fins as paddles and supports.

The well-known figure by Klaatsch shows the pectoral limb of *Polypterus* compared with that of an amphibian. However, these are not really homologous views, since in order to get in its present position the amphibian limb has turned over to form an elbow, whereas the pectoral limb of *Polypterus* is simply bent forward. Consequently it is resting with the extensor surface instead of its flexor surface applied to the ground.

The diagram of Romer and Byrne (1931: fig. 6) shows very well the probable stages in the postural changes undergone during the evolution of the pectoral appendage (FIGURE 16). Their figure "A" shows the position assumed by the pectoral fins in such forms as *Ceratodus* and *Polypterus*. The ventral surface is turned outward, not inward; the preaxial margin is dorsal, not ventral. To bring the ventral surface in contact with the ground a sharp twisting of the entire limb is necessary, as shown in "B," resulting in the tetrapod elbow joint. Once this has been accomplished, little further adjustment is necessary to bring the manus into its definitive position—"C." This manner of twisting was a very important feature, as Romer pointed out.

Studies on the innervation of the pectoral limb of vertebrates, from fish to man, have shown that the nerves closer to the head supply the preaxial border of the fin or limb and that those more caudally placed innervate the postaxial border of the fin or limb and that all these nerves have dorsal and ventral divisions. The dorsal divisions innervate the muscles and skin on the primitive dorsal or extensor surface of the limb and the ventral divisions innervate the muscles and skin on the ventral or flexor aspect of the fin or limb (Howell). FIGURE 17 from Gregory

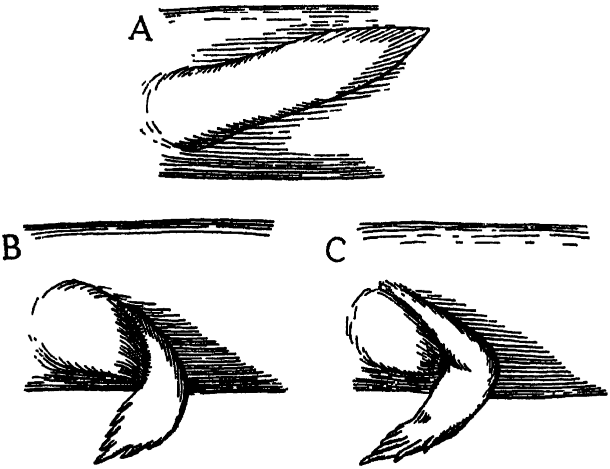

FIGURE 16. "Probable stages [Romer and Byrne] in the postural changes undergone during the evolution of the pectoral appendage . . . In A is shown the position assumed by the pectoral fin in such forms as *Ceratodus* and *Polypterus*. Here, in contrast with the pelvic fin, the ventral surface is turned outward, not inward, the preaxial margin is dorsal, not ventral, as in the pelvic fin . . . To bring the ventral surface in contact with the ground a sharp twisting of the entire limb is necessary (B), resulting in the tetrapod elbow joint. Once this has been accomplished, little further adjustment is necessary to bring the manus into its definitive position (C)." (Romer & Byrne 1931: 36, fig. 6.)

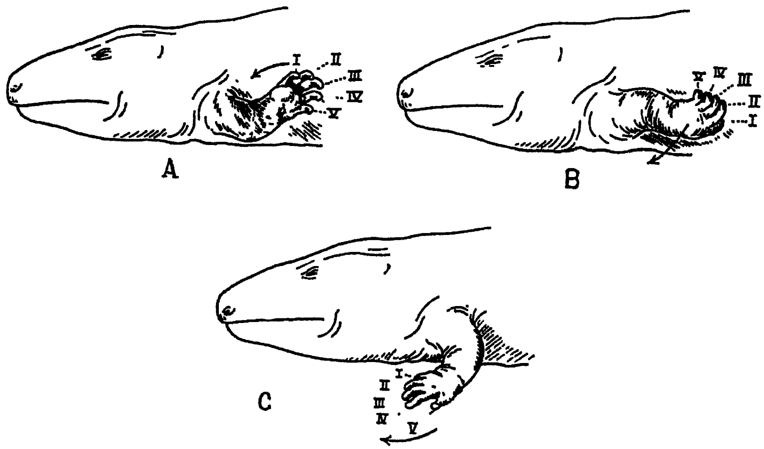

FIGURE 17. Two possible modes of twisting of the pectoral and pelvic limbs. A. Palmar surface of the future hind limb turned outward, first digit uppermost. Subsequent rotation of limb in direction of arrow. B. Palmar surface turned inward, first digit on ventral border. Subsequent movement of limb in direction of arrow. C. Primitive tetrapod position, with first digit on inner side and short fifth digit on outer side. (From Gregory 1928: fig. 8.)

(1928: fig. 8) shows how the limb may be rotated so as to assume the tetrapod position. In "A" the limb is appressed to the side of the body with the first digit uppermost. "C" shows the same limb rotated forward so that the first digit is on the inside, nearest to the body. "B"

shows the limb appressed to the body with the fifth digit uppermost. From this position if the arm is simply turned forward the resultant position would also be that shown in Figure "C." Consequently, if we have the first digit uppermost with the palmar surface out and bend the limb forward so that the palmar surface comes in contact with the ground, or if we have the fifth digit uppermost and the palmar surface in toward the body and then rotate the limb forward so that the palmar surface comes in contact with the ground, the result will be as in Figure "C" in both cases. This diagram was designed to show two different ways in which a pectoral fin might be twisted into the tetrapod position but, as we now know, "A" and "B" actually show two successive phases in the rotation from "A" to "C." In other words, "B" is an intermediate, not an alternative stage.

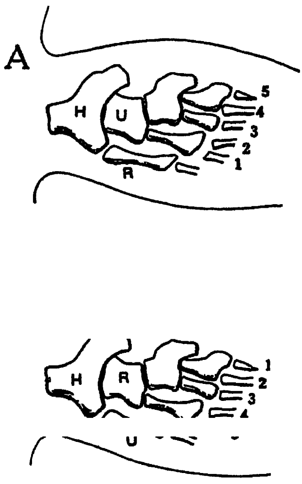

FIGURE 18. "A. Usual interpretation of the orientation of the crossopterygian pectoral fin, and identification of skeletal elements (simplified after Gregory 1928). B. Correct interpretation. H, humerus; R, radius; U, ulna; 1, 2, 3, 4, 5, assumed order of digits." (From Romer & Byrne 1931: fig. 9.)

In Romer's diagram (FIGURE 18) of the bones of the pectoral fin in *Eusthenopteron*, "A" shows Gregory's interpretation of the elements. This, we believe now, correctly identifies the elements but did not correctly rotate the fin in its change toward the tetrapod condition; consequently the extensor surface of the manus would have been applied to the ground. Romer, on the other hand, misidentified the radius, ulna and digits; consequently he placed in diagram "B" the mesomeral axis of the fin along its dorsal border which he regarded as originally preaxial.

This we now know to be incorrect from the reexamination of many fossil specimens and more comparative material.

In the type specimen of *Sauripterus* (FIGURE 19) the mesomeral axis can be clearly seen along the postaxial border of the fin. The preaxial border of the fin can be recognized by the stiffer marginal rays.

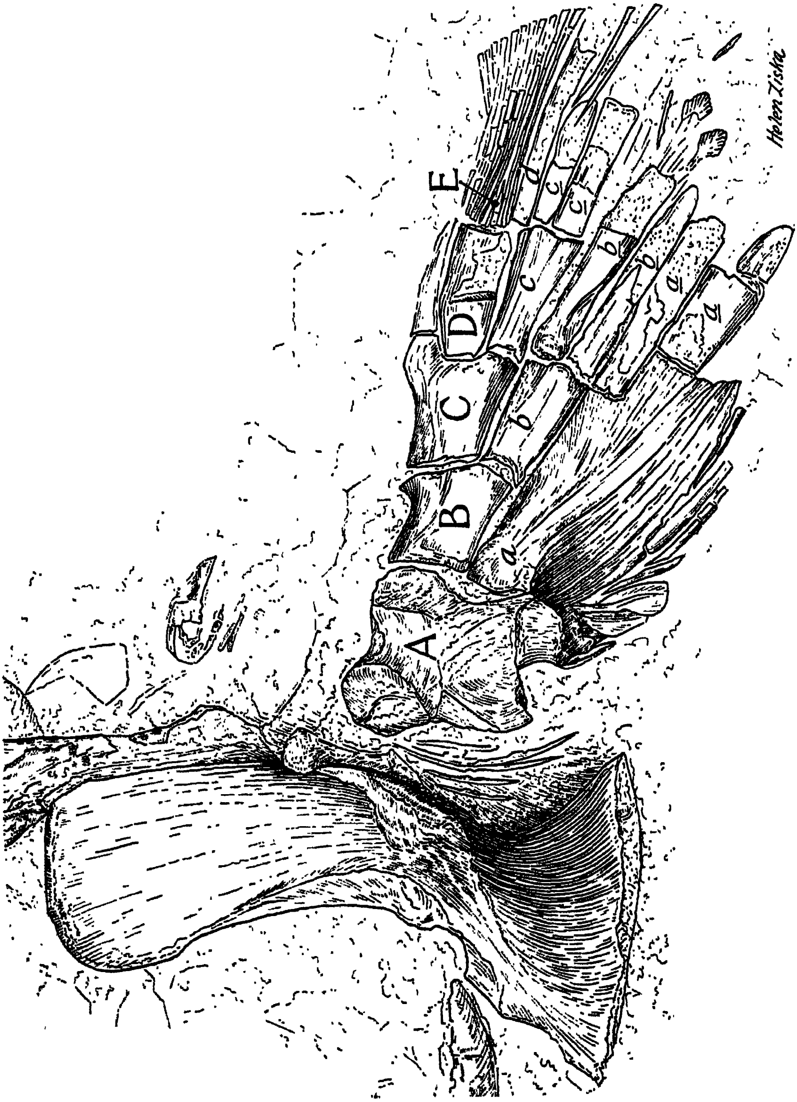

FIGURE 19. Revised drawing of the pectoral girdle and paddle of *Sauripterus taylori* Hall. × ½. Note imprint of horny rays attached to bone a.

The outline of the fin of *Sauripterus* shows the method adopted by us for naming the bony segments of this type of limb. The mesomeral axis is labelled with capital letters, whereas the radials are represented by small letters, radial "a" being attached to mesomere "A"; radial "b" to mesomere "B," etc.

We find the most primitive conditions of the pectoral fins and girdles in such forms as *Acanthodes*, *Ctenacanthus*, and *Cladoselache*. The pectoral fins (FIGURE 20) of these three forms were all broad-based and the

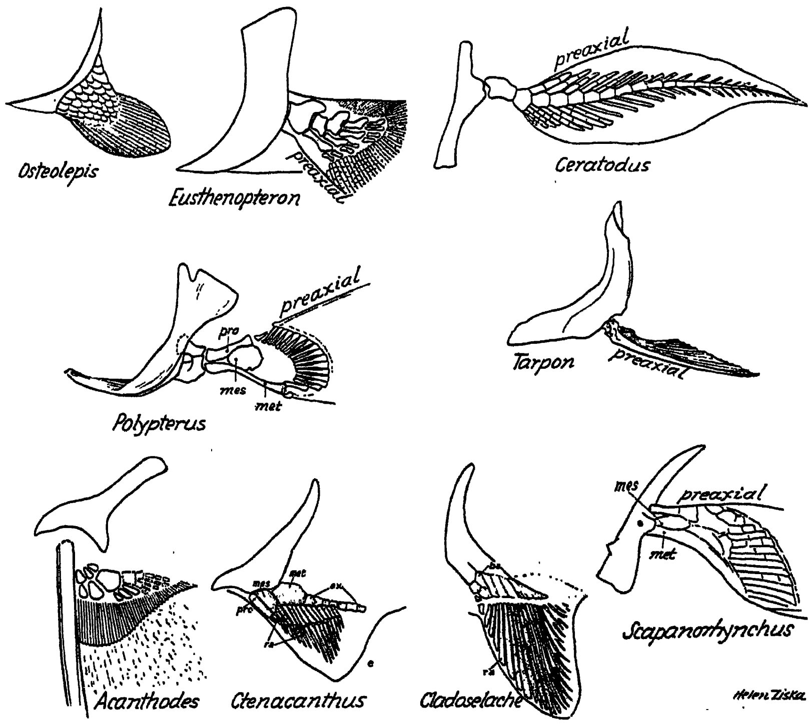

FIGURE 20. Series showing pre- and postaxial borders of the fin in fishes. *Osteolepis*. After Goodrich. *Eusthenopteron*. After Bryant. *Ceratodus*. After Rabl, in part. *Polypterus*. After Goodrich, in part. Tarpon. From specimen. *Acanthodes*. After Watson. *Ctenacanthus*. After Moy-Thomas. *Cladoselache*. After Dean. *Scapanorhynchus*. From specimen.

fins stood out more or less at right angles to the body. *Osteolepis* shows the beginning of a paddle-like fin. In the modern deep-sea shark, *Scapanorhynchus*, the base of the pectoral is narrow enough so that the preaxial border may be turned either up or down. When the preaxial border is raised we see the ventral or flexor surface of the fin. *Polypterus* and *Ceratodus* both habitually hold the preaxial border of the pectoral

fin up so that the flexor surface is outward. *Eusthenopteron*, on the other hand, on the basis of a number of specimens, died with the preaxial border of its fin turned downward. Thus the flexor aspect would be appressed to the side of the body. In all cases the mesomeral axis is on or near the postaxial border of the fin, whereas the radials extended toward the convex preaxial border. The tarpon and other isospondyls rest with the preaxial border of the pectoral fin directed downward but all the higher bony fishes have it directed upward.

The question might be raised whether the "preaxial" border of fishes is truly equivalent to that of tetrapods. The evidence cited by anatomists, however (*e.g.*, Howell), and verified by one of us seems to give an affirmative answer (FIGURE 21).

That we might better visualize the changes that took place in the evolution of these forms, one of us (H.C.R.) constructed a large model

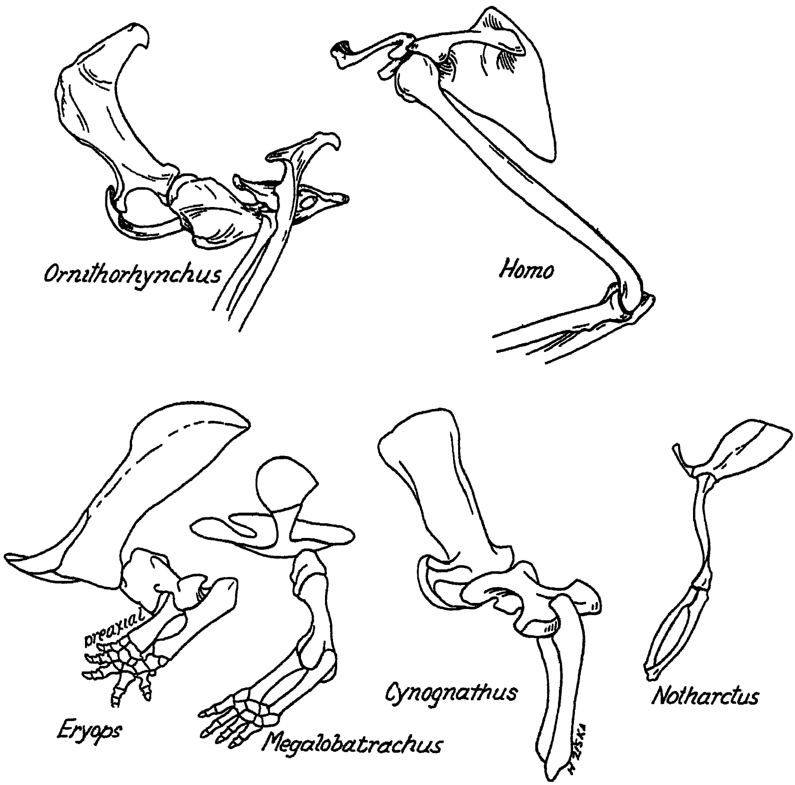

FIGURE 21. Primitive and later position of limbs in primitive amphibian, mammal-like reptile, monotreme, primitive primate (*Notharctus*) and man.

(PLATES 4, 5) of the pectoral fin of *Eusthenopteron* that could be twisted, to which wires were attached to represent nerves. The model was first posed with the pectoral fin shown in the position in which it is usually held in sharks (PLATE 4); that is, with the mesomeral axis close to the body and the radials directed toward the preaxial border of the fin.

In *Eusthenopteron* the preaxial border (PLATE 4B) must have been directed downward, for this is how it is preserved in a number of fossil specimens. The stiff rays represent the preaxial border of the fin, whereas a series of fine rays represent the postaxial border.

Next (PLATE 5C) the model is put into the position taken by *Polypterus* and *Ceratodus* when they are at rest.

In the final stage (PLATE 5D) in the transformation from fish to tetrapod there is a sharp bend in the fin at the shoulder and then another to form an elbow joint. The first mesomere ("A") is equivalent to the humerus.

The second mesomere ("B") equals the ulna and the first radial ("a") becomes the radius. The remaining elements become carpals, whereas the metacarpals and phalanges are formed later as new distal digital outgrowths (See below, p. 323).

Romer forgot to twist the pectoral fin of *Eusthenopteron* so that the first radial ("a") would be dorsal. He supposes in his figure 9B (FIGURE 18) that the processes on the mesomeres were on the preaxial border. In this point the evidence indicates the reverse.

An important part of the general problem relates to the questions, when, how, and from what parts of the rhipidist paddle were the tetrapod metacarpals (or metatarsals) and digits, derived? Previous theories (FIGURES 22, 23) have selected either the fourth (Watson 1913) or the fifth digit (Holmgren 1939: 93) of tetrapods as the lineal descendant of the mesomeral axis of the rhipidist paddle, which in such diagrams is always shown with a straight axis and branching rays. In 1935 one of us (Gregory 1935: figs. 3, 4) suggested (FIGURE 24) that as the elbow bend was formed the second mesomere became elongated to give rise to the ulna and that consequently the more distal mesomeres were turned toward, and crowded into contact with, the remaining radials. It is the oblique twist of the mesomeral axis and the transformation of its mesomeres into intermedium, centrale 1, 2, which has conditioned the oblique arrangement of the carpals (tarsals) in the earliest known tetrapods.

We wish now not only to reaffirm the foregoing interpretation of the morphologic data but to suggest that carpalia (tarsalia) 1–5, all the metacarpals (metatarsals) and digits represent a proliferation of a distal-

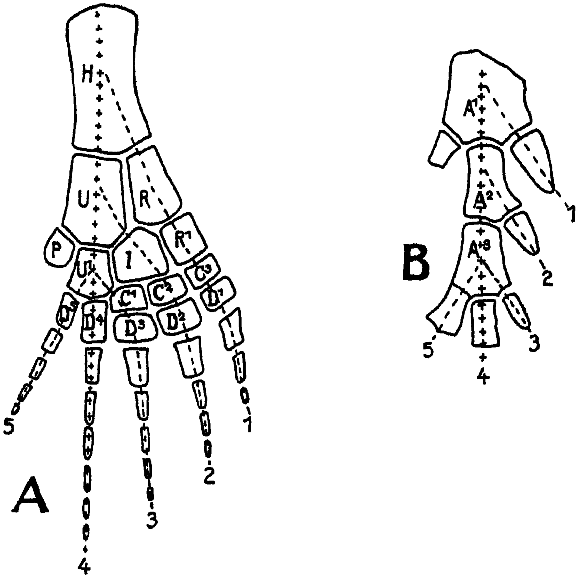

FIGURE 22. "A. Diagram of the supposed primitive tetrapod limb. The dotted line from H to 4 is the axis, the branch dotted lines ending in 1.2.3. represent preaxial, and that to 5 a postaxial, radii. H = humerus. U = ulna. R = radius. P = pisiform. U' = ulnare. I = intermedium. R' = radiale. C', C'', C''', = first, second and third centralia. D'- D, = first to fifth distal carpals. B. Endoskeleton of the pectoral fin of *Eusthenopteron*. A' – A''' = first to third axial elements." (From Watson 1913: figs. 1, 2.)

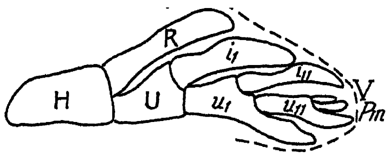

FIGURE 23. Pectoral fin skeleton of *Eusthenopteron foordi*. (From Holmgren 1939 fig. 2.)

postaxial marginal zone bordering the fleshy or muscular lobe of the paddle and located largely on its originally postaxial margin. In other words, the original skeleton of the rhipidist paddle is to be sought chiefly in the more proximal elements of the carpus (tarsus), while the carpalia (tarsalia), metacarpals (metatarsals) and digits were neomorphs, so to speak, that were developed when the paddles began to serve as legs. Moreover this fleshy or muscular lobe, containing the future extensor muscles on the old laterally-facing surface and the future flexors on the old medially-facing surface, grew distally as the limb buds became longer, while the dermal rays (lepidotrichia) became shorter and more

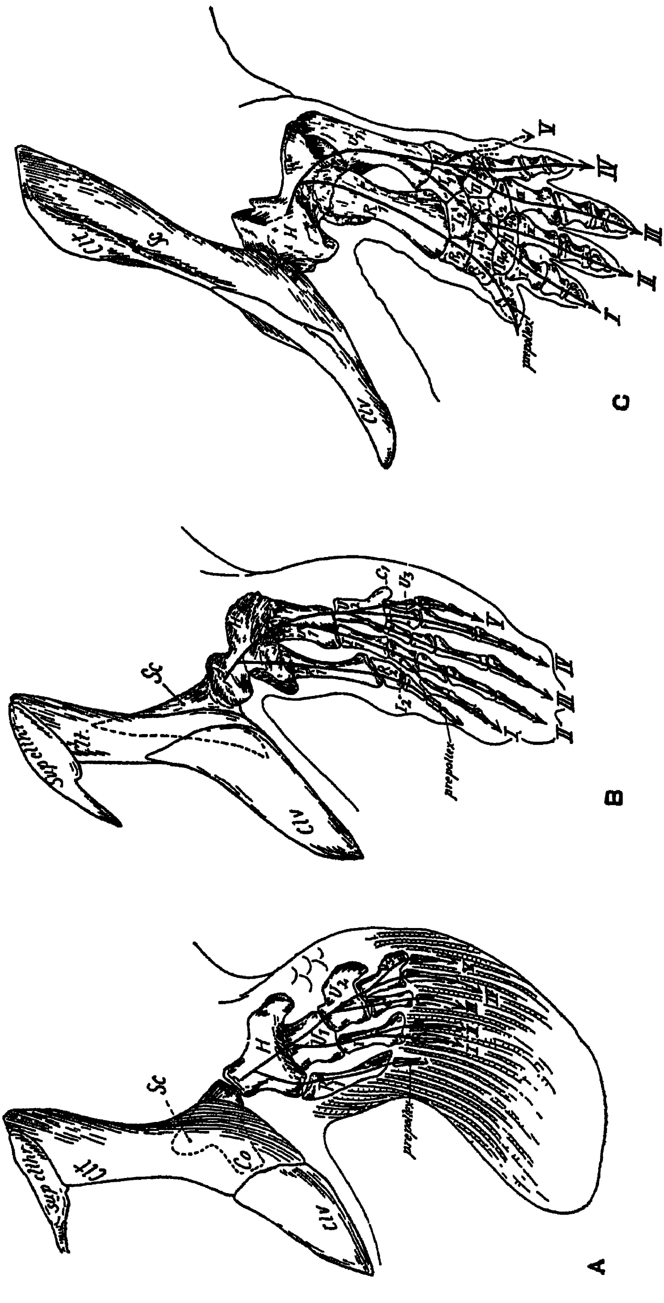

FIGURE 24. Transformation of crossopterygian pectoral girdle and paddle into pentadactylate type. Gregory's theory. Oblique front view of left side. A. *Eusthenopteron foordi* Based on material of Bryant and Gregory. B. Partly hypothetic intermediate. Girdle supplied from Watson's *Eogyrinus*. C. *Eryops megacephalus*. Based on Cope's material in the American Museum.

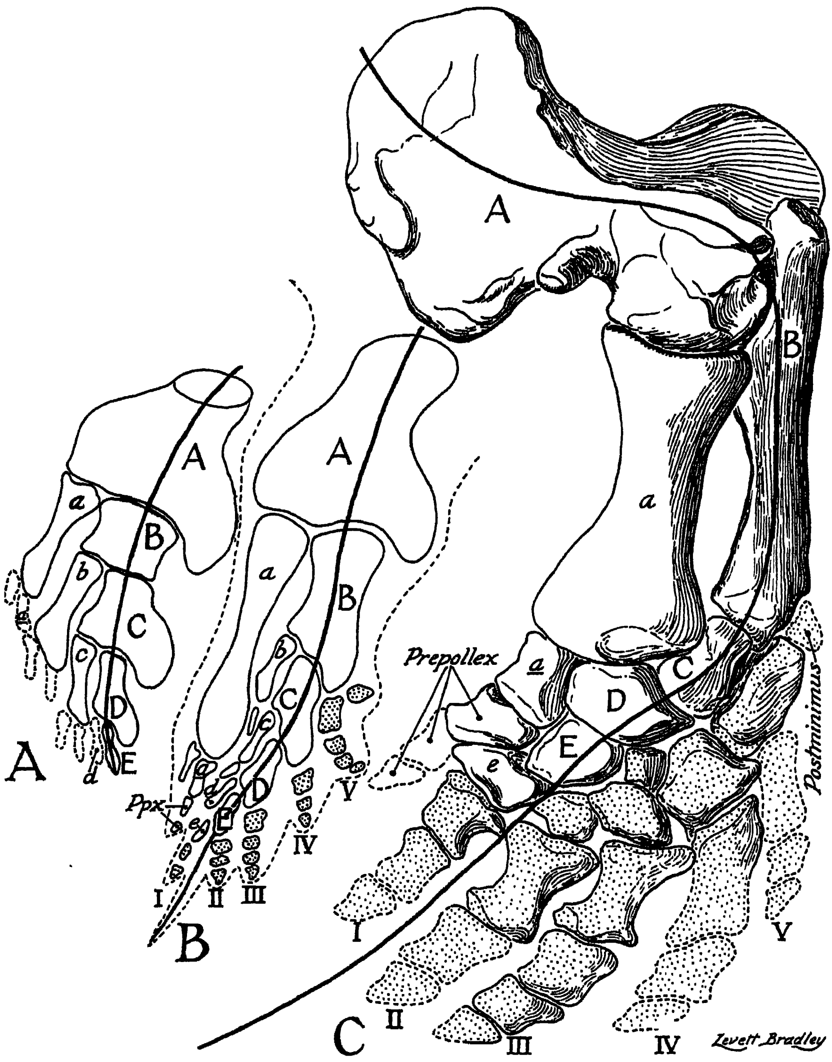

FIGURE 25. Suggested derivation of primitive amphibian appendage (C) from *Eusthenopteron* type (A) by passing through graphic intermediate (B). (B) In *Eryops* the cast of the skeleton of the foot has been sawed apart and the individual bones reassembled.

delicate. Evidently the flexors and extensors did not grow peripherally as continuous masses but early became subdivided radiately, so that the postaxial border of the paddle became emarginate or sinuate, the projecting lobes giving rise to the digits. In short we are suggesting that the tetrapod carpals, metacarpals (metatarsals) and digits were the

product of what may be called a digitiferous border on the postaxial side of the paddle.

Upon reviewing the embryological evidence from recent amphibians analysed by Holmgren (1933, 1939), we find that our theory as set forth above agrees perfectly with his, except for his phylogenetic implications, which will be discussed below.

We agree with him also in the reduction and loss of the rhipidist radials (b, c, d) lying between the first radial (a = radius) and the fifth mesomere (E = centrale 2).

The foregoing hypothesis evidently differs from that proposed by Broom (1913), who suggested (FIGURE 26) that the digits grew out from

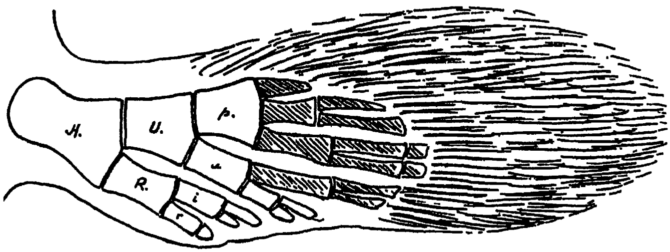

FIGURE 26. "A fin representing the supposed pre-*Sauripterus* stage. The elements are as in *Sauripterus* without the specialisation. The elements shaded are those that will be lost when the appendage ceases to be a fin. H, Humerus; R, Radius; U, Ulna; i, Intermedium; p, Pisiform; r, Radiale; u, Ulnare." (Broom 1913: 463, fig. 6.)

the preaxial side. Broom's idea was suggested by the peculiar finger-like development and functions of some of the preaxial rays of the pectoral fins of the sea-robin, or gurnard. But few fish could be more unlike the pro-tetrapods than these, especially in their fin skeletons. And whereas Broom offered no evidence at all that the pro-tetrapods did develop their limbs from a gurnard-like stage, we are submitting direct morphologic and phylogenetic evidence that the tetrapods were derived from the rhipidist stem and that all the bones of the carpals and tarsals of the primitive tetrapods may be satisfactorily accounted for approximately as follows:

FORE LIMB

Rhipidist and postrhipidist (*) stages	Primitive tetrapod
I. Mesomeres and their distal buds	
First mesomere (A)	Humerus
Second mesomere (B)	Ulna
Third mesomere (C)	Intermedium
Fourth mesomere (D)	Centrale proximale (C4)
*Fifth mesomere (E)	Centrale distale (C2)

II. Postaxial buds

From second mesomere (B)	Postminimus
From third mesomere (C)	Ulnare, carpale 5*, mtc. 5* and digit V*
From fourth mesomere (D)	Carpale 4*, mtc. 4* and digit IV* Centrale 3 Carpale 3*, mtc. 3* and digit III*
*From fifth mesomere (E)	Carpale 2*, mtc. 2* and digit II*

III. Preaxial radials

First radial (a)	Radius
Distal buds from (a)	Radiale Centrale 1 Prepollex
Second radial (b) and its distal buds	Lost
Third radial (c) and its distal buds	Lost
Fourth radial (d) and its distal buds	Lost
Fifth radial (e) and its distal buds	? Carpale 1, mtc. 1 and digit I

HIND LIMB

Rhipidist and postrhipidist (*) stages	Primitive tetrapod (*Trematops*)
I. Mesomeres and their distal buds	
First mesomere (A)	Femur
Second mesomere (B)	Fibula
Third mesomere (C)	Intermedium
Fourth mesomere (D)	Central proximale (navicular)
*Fifth mesomere (E)	Centrale distale (mediale 2)
II. Distal and/or postaxial buds	
From second mesomere (B=fibula) distal buds	Fibulare*, postminimus* Tarsale 5* ? Mts. V* and digit V*
From third mesomere (C=intermedium) postaxial buds	? Lost or fused with fibulare
From fourth mesomere (D=centrale proximale)	Tarsale 4*, mts. IV* and digit IV* Centrale, distale, fibulare* (Holmgren) Tarsale 3* Mts. III* and digit III*
From fifth mesomere (E*=centrale distale)	Tarsale 2* Mts. II* and digit II* ? Tarsale 1*, mts. I* and digit I*
III. Preaxial radials	
First radial (a) and its distal buds* (*a*,phx)	Tibia, tibiale* and prehallux* (y)
Second radial (b) and its distal buds	Lost
Third radial (c) and its distal buds	Lost
Fourth radial* (d) and its distal buds*	? Tarsale 1*, mts. I* and digit I*

Whether or not our theory of the derivation of the tetrapod carpals and tarsals be a rough approximation to the facts, the foregoing tables reveal radical differences in the methods of naming the supposedly homologous parts in rhipidist paddle and tetrapod limb. These differences arise first from the fact that even in the oldest known tetrapods the names of the carpals and tarsals are parts of a system in which the bones have been thought of as being arranged in transverse rows, as they are in mammals. As an example we have only to recall the names of the "proximal" row (radiale, intermedium, ulnare) and of the distal row (carpalia 1, 2, 3, 4, 5). The "centralia" did not fit well into this "transverse system" (FIGURE 27).

Our system of names, on the other hand, considers the skeleton of the tetrapod appendage to be derived from a rhipidist paddle (FIGURE 25), in which the mesomeres, originally postaxial in position, become twisted toward the preaxial border in such a way that the more distal mesomeres (C, D, E) gave rise to the oblique row consisting of the intermedium and centralia 1, 2.

As noted above, according to our theory the rhipidist paddle was bent and twisted so that the mesomeres (B, C, D, etc., and their radials, b, c, d, e, f) were pressed against the first radial (a) and its distal buds (*a*, ppx). Hence the tetrapod carpus (or tarsus) is divided into two very unequal parts, the first part consisting only of radiale and the so-called prepollex (prehallux), the second part including all the remaining carpals, which collectively converge proximally toward the ulna (fibula). All the carpalia (tarsalia) 1–5 and their numbered digits (I–V), including the pollex (hallux) according to our theory (FIGURES 25, 27, 28) arose from the digitiferous zone on the distal and postaxial margin of the rhipidist paddle and are thus analogous to some extent with the postaxial rods in the paddle of *Ceratodus* and with the embryonic tissue which gives rise to the digits (Steiner, Holmgren). We are aware that Brazier Howell (1935a) claims that there is no evidence for the existence of a prehallux (prepollex) in the ancestral tetrapod. But we also know that in the manus of Cope's type of *Eryops megacephalus* (FIGURE 27) there is a sharply marked articular surface on the distal end of the well preserved proximal element of the prepollex (=y of Holmgren). If *prepollex* is not permissible for the missing bone, we may compromise by calling it "prepollex" in quotes; but it seems well established that in the manus there was a preaxial series consisting of radius, radiale, and "prepollex" which was quite distinct from the rest of the manus, while in the pes the preaxial series consisted of the tibia, tibiale, the y-bone and "prehallux."

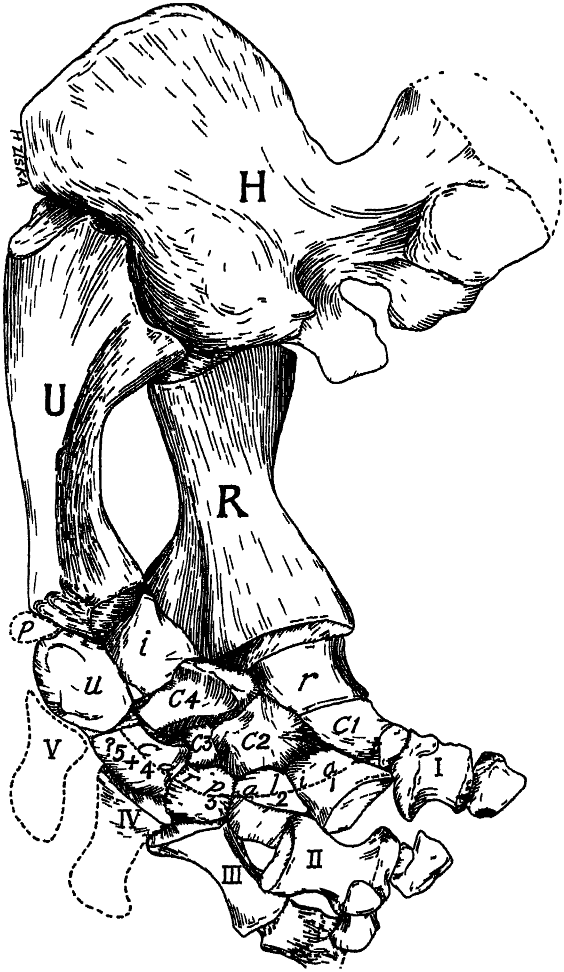

FIGURE 27. Forelimb of *Eryops*. Flexor surface with "amphibian" names of bones × ½.

From all the foregoing it is evident that if our theory be true, the most conspicuous skeletal parts of the tetrapod appendages, which are the carpalia, metacarpals and phalanges, must have originated as a result of the proliferation of the "digitiferous zone" as defined above. In the rhipidist stage as we know it the distal ends of the flexor and extensor masses were separated both by the skeleton of the paddle and by the dermal rays. There is good reason to suppose that when the whole weight of the body came to rest upon the paddles, a sharp flexure line would be developed between the fin-ray web and the fleshy lobe. At

first the fin-ray web would have sufficient resiliency to serve as a spring, as is the case in the enlarged pectoral fins of the mud-skipping goby. But all the evidence suggests that in the post-rhipidist stage there would be a rapid, genetically predetermined retrogression of the fin-rays, such as is known to have occurred in the Dipnoi. In this way the "digitiferous zone" would gradually be the locus of the converging stresses of the flexor and extensor surfaces; it would become the main zone of contact between the fin and the ground; as the muscular lobe extended peripherally it became subdivided into five emarginated projections from which the future carpals (tarsals), metacarpals (metatarsals) and digits developed; and as they developed they carried with them especially the tendons of the flexors and extensors, which are inserted in the terminal phalanges. The increase in number of phalanges is analogous with that which took place later in the paddles of such secondarily aquatic forms as ichthyosaurs, plesiosaurs, and whales.

Meanwhile, we infer, the radials (b, c, d) in front of the mesomeral axis, which form an important part of the rhipidist fin, gradually atrophied. That there was an anisomerous growth (or emphasis) of certain parts of the appendage need cause no surprise in view of the radical transformation in the skull and in most of the other parts of the skeleton between the rhipidist and tetrapod stages.

If this theory be true, the most primitive of the footprints of early tetrapods ought to be those in which the carpal or tarsal parts of the footprint are large in proportion to the digital parts. Such footprints have been named *Nanopus maximus, Baropus, Agastopus, Parabaropus,* etc. (Gilmore 1927).

PART IV

A NEW THEORY OF THE ORIGIN OF THE PELVIS OF TETRAPODS

In the pelvic limb (FIGURE 28) the transformation is less complicated than in the pectoral limb. The fin of necessity becomes narrow at the base so that it may swing forward. There is no twisting as in the pectoral limb but merely a bending to form a knee and ankle joint. Romer's figure 5 (FIGURE 29) admirably illustrates what took place if we make allowances for the limb's being attached much too high on the side of the body. The pelvic limbs to begin with are beneath the body and

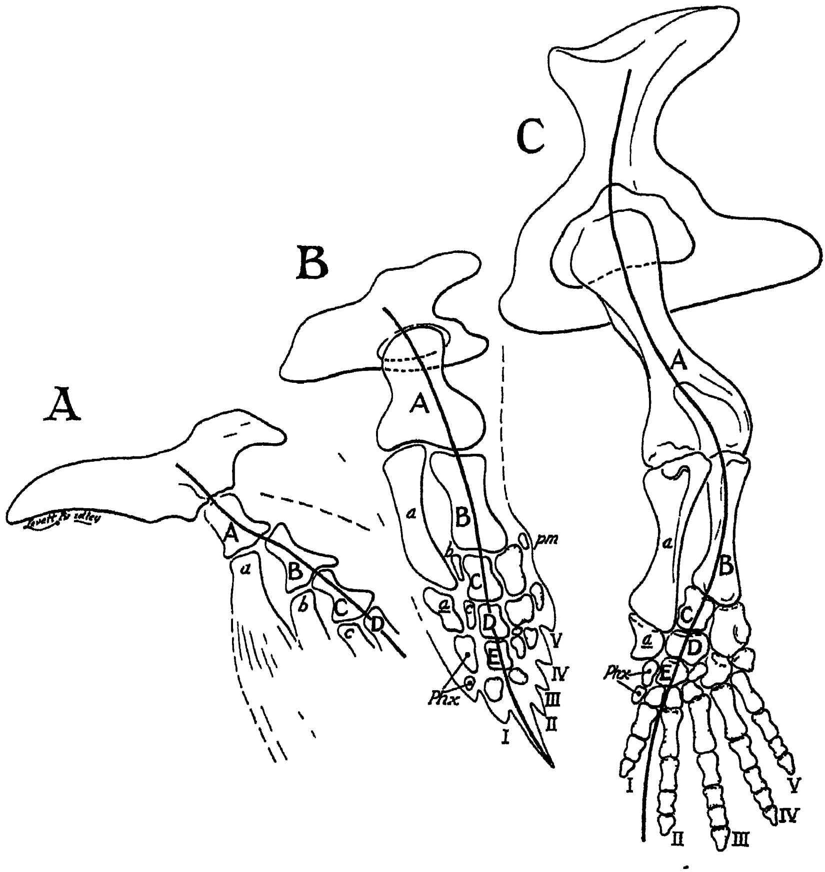

FIGURE 28. Pelvis and pelvic appendages of A. *Eusthenopteron*, B. graphic intermediate; C. *Trematops* (pelvis restored)

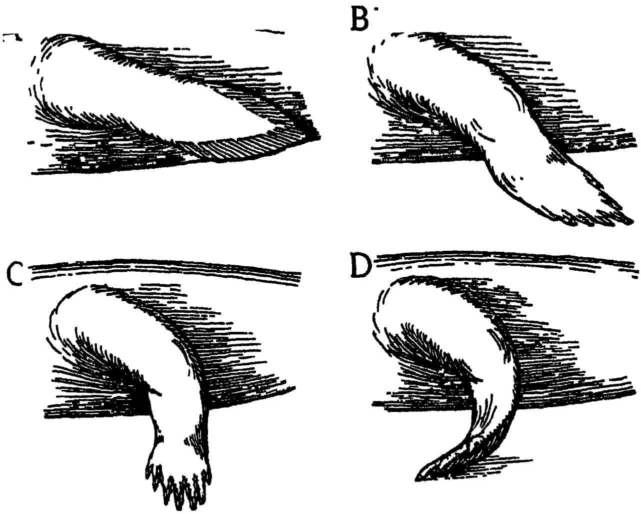

FIGURE 29. "Diagrams (after Romer and Byrne) illustrating the probable changes in position during the evolution of a pelvic fin into a tetrapod pelvic limb. In A the fin is shown enlarged to tetrapod size, but in a position comparable to that found in *Ceratodus* and *Polypterus*, with the true dorsal surface turned outward and somewhat dorsally . . . A double flexure, creating knee and ankle joints would result in placing the limb on the ground, but with the foot directed backward (B). The proper orientation of the foot has been accomplished (C, D) by a marked rotation of the tarsal and digital region, which, it has been suggested, would account for many of the structures and structural tendencies seen in the primitive tetrapod pelvic limb." (Romer & Byrne 1931: 34, fig. 5.)

already in an efficient position. "A" shows the pelvic fin with its dorsal aspect exposed and its flexor surface appressed to the body. "B" shows the development of knee and ankle. "C" and "D" show the accomplishment of the tetrapod position. When this tetrapod position is finally acquired the bends in the fore and hind limbs are in opposite directions, the knee pointing forward and outward and the elbow pointing backward and outward.

Romer's figure 7 (FIGURE 30) illustrates the contrast in posture be-

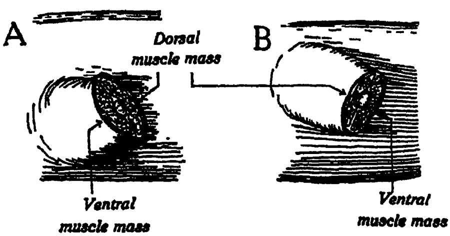

FIGURE 30. "Diagrammatic section to illustrate the contrast in posture between the pectoral and pelvic fins in fish. A. Pectoral fin . . . The position of the ventral (flexor) and dorsal (extensor) muscle masses is indicated; the demarcation between them represents the plane of the fin. The preaxial margin is (roughly) dorsal, the postaxial nearly ventral in position. B shows the contrasted position of the pelvic fin . . ." (From Romer & Byrne 1931: fig. 7.)

tween the pectoral and pelvic fins in a fish. In the pectoral fin the ventral or flexor muscle mass is directed ventrolaterally. In the pelvic limb it is directed ventromedially. In the pectoral limb the dorsal or extensor mass is dorsomedial and in the pelvic fin the extensor mass is dorsolateral.

A dissection of *Megalichthys* (FIGURE 31), one of Cope's specimens from the Permian of Texas, shows that the pelvic fin was even more limb-like than in *Eusthenopteron*. What we interpret to be the pelvis is a simple

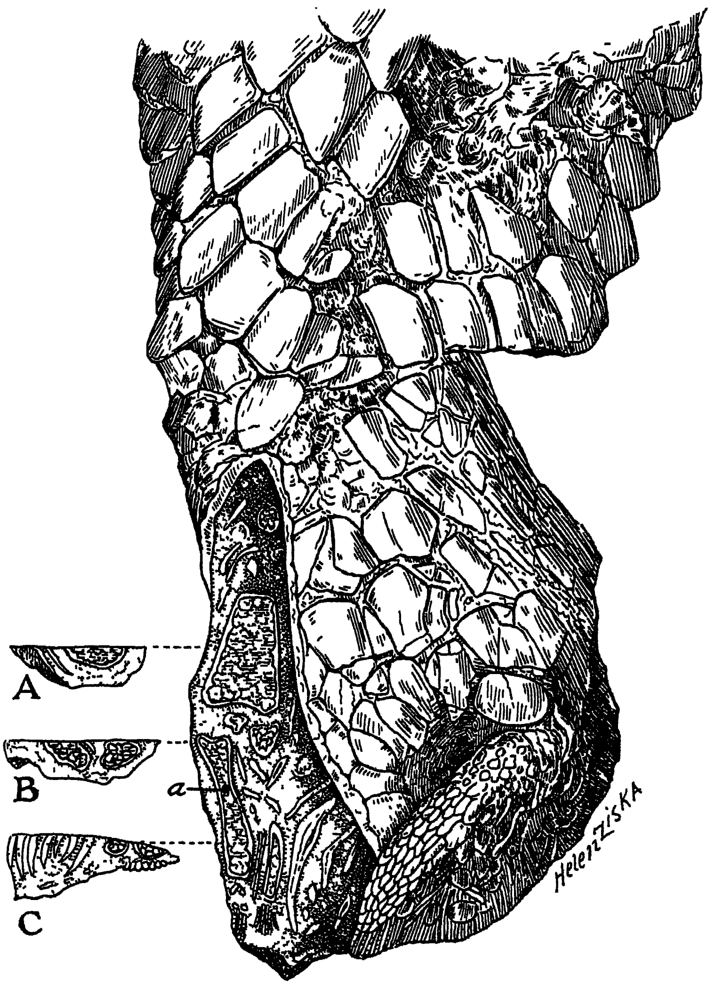

FIGURE 31. Part of type of *Megalichthys nitidus* (Cope) with dissection of the pelvic base and appendage. × 1.

broad rod ("A"). The distal end of the pelvic rod shows an acetabulum directed caudally.

In the pelvic limb it will be seen that the mesomeral axis is on the postaxial border of the fin, just as in the pectoral fin. The first mesomere ("A") becomes the femur; "B" becomes the fibula; the first radial ("a") becomes the tibia. With the aid of the remarkable specimen (FIGURE 13) collected by Dr. Horace E. Wood, 2nd, it has been possible to understand the evolution of the pelvis much more clearly than ever before. In the pelvis of *Eusthenopteron* the acetabulum is on the posterior border; there is a long pubo-ischiadic plate and just the beginning of an iliac process rises from this plate. The mere presence of an iliac process is evidence that its possessor had need to raise the limb, for the iliac process would be in an appropriate position to serve as the point of origin for levator muscles inserting on the fin.

The probable changes (FIGURE 32) which must have taken place between this crossopterygian fish and a palaeozoic amphibian involved first a shift in the position of the acetabulum so that it faced laterally and was at the center of a triradiate bony structure in order that the limb might be drawn forward, backward and upward. The extension of the ischium backward clearly indicates the power that could be exerted to pull the limb back, thus propelling the body forward.

Thus according to present evidence the primitive tetrapod pelvis arose from the following changes:

(1) The first changes, as noted above, were the shifting of the acetabulum from the posterior end to the lateral surface (FIGURE 33), the correlated caudad elongation of the ischial process and the dorsad extension of the iliac process.

(2) The dorsal prong of the ilium, extending upward into the axial musculature, caused, or at least made possible, the separation of that musculature into iliocostalis and iliocaudalis parts. Thus the pelvis, originally a structure of no direct importance, in the lateral flexure of the body became a fulcrum for the alternate lateral swings of the presacral and postsacral parts.

(3) The fulcral effect of the opposite ilia was increased finally to a maximum degree by the mutual interaction and, as it were, attraction between the up-growing medial sides of the ilia and the down-growing lateral surfaces of the future sacral ribs. However, the development of a fairly firm connection between the pelvis and the vertebral column by way of the sacral ribs was a later phase of evolution, as to which we have abundant evidence in the tetrapods of late Palaeozoic and early Mesozoic eras.

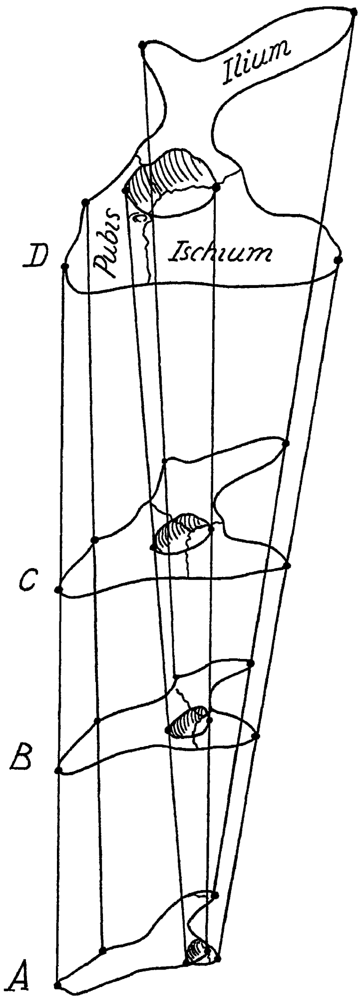

FIGURE 32. Suggested series, showing probable changes in ilium, ischium, pubis, from fish to tetrapod. A. *Eusthenopteron*, B C. graphic intermediates, and D. primitive amphibian, essentially *Diplovertebron*.

(4) The evidence suggests that long before the sacro-iliac connection became important, the opposite halves of the pelvis (ossa innominata) had gained mutual support by strengthening and enlarging the symphysis pubis. All the early tetrapods, so far as known, had already attained the stage with a strong symphysis pubis; but in not a few of them the ischial portions of the pubo-ischiadic bones were still divergent poster-

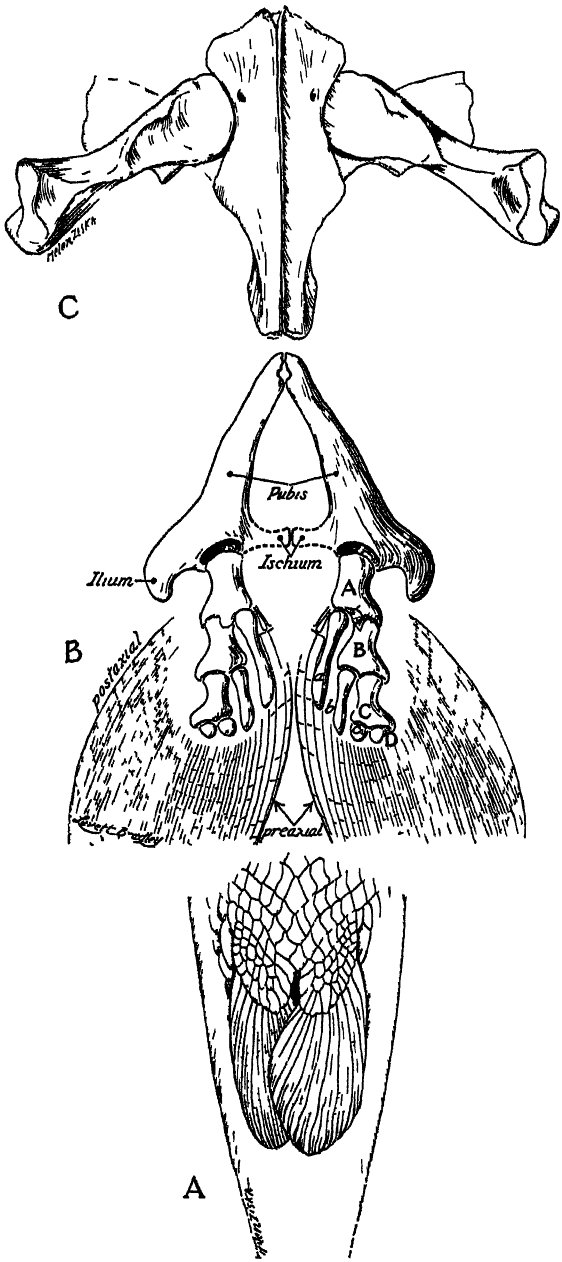

FIGURE 33. A. Pelvic appendage of *Polypterus*, directed backward; B. *Eusthenopteron*, restored, C. Pelvis and femora of *Eryops*, ventral view, showing acetabula on lateral surfaces of pelvis.

iorly. The ischial symphysis then developed as the opposite ischia grew wider, with the increase in bulk of the retractor (obturator) muscles of the femora.

(5) As the rhipidist paddle grew and transformed itself into the tetrapod limb we may fairly suppose that the embryonic limb bud became more and more potent as an organizing center, influencing not only its own constituent parts but also the genetically related pelvic bones. Of the constituent parts of the limb bud it seems probable that the most important, in terms of their influence upon the pelvic bones, would be the opposite femora and the muscle masses by which the femora were surrounded. Or, to put it the other way around, there was a mutual "action, reaction, and interaction" between the pelvic bones and the limb bones.

In a far earlier stage the pelvic bones themselves had originated as bases for the appendages. At first they were simply processes growing forward from the base of the fin; in the rhipidist stage they had developed two branches in front of the acetabulum, a long anterior branch, the future pubis, and presumably a very short medial branch, the future ischium; as the limb bud shifted laterally a dorsal branch, the ilium, arose, as noted above (FIGURE 32). Thus we have each innominate bone potentially tripartite, but how did it actually become divided into three parts by a triradiate suture centering in the middle of the acetabulum? From the tripartite construction of each innominate bone and from the triradiate form of their sutural juncture in tetrapods it follows that each of these bones may be viewed as analogous with a diaphysis if the other two are thought of as epiphyses, but we are not sure that this is anything more than a morphological metaphor. Again, we may think of each of these bones as serving in turn as a keystone for an arch formed by the other two, the whole forming a system of three trusses with a common center. In like manner it is easy to conceive the primitive ilium, as least in its lateral aspect, as resisting the resultants of the thrusts from the femur by muscles acting respectively from the anterior and posterior divisions of the pubo-ischiadic plate; the pubis, moreover, is tied to the abdominal muscles in front, while the ischium is tied to the ventral caudal muscles behind. In short, after the tripartite innominate bone had attained its commanding strategic position it is easy enough to see various ways in which its triune nature and its tripartite construction were mutually advantageous and even necessary, both to each other and to the entire economy. But with reference to FIGURE 32 exactly what were the intermediate stages in the evolution of the triradiate suture between A and D?

In order to encourage further morphologic research on this problem we propose the following trial hypotheses:

(1) That, by analogy with the better known history of the pectoral girdle, the first part to become emancipated was the ilium, which may have arisen possibly as an apophyseal knob above the acetabulum, *pari passu* with the increase of the m. extensor femoris. By subsequent growth this iliac "apophysis" extended its sutural boundary downward into the dorsal third of the acetabulum. Thus we would have a division into one dorsal branch, the ilium, and a single ventral base, the pubo-ischiadic plate, corresponding to the undivided coracoid of the primitive tetrapods. Again by analogy, the apparently sudden division of the ventral plate into two subequal parts was no major morphological achievement since it evidently did occur when the single coracoid of the primitive cotylosaurs became subdivided into the anterior and posterior coracoids of the pelycosaurs and therapsids. This hypothesis supposes a gradual upgrowth of the ilium and a rather sudden subdivision of the ventral plate into pubis and ischium.

(2) Our second and preferred trial hypothesis (FIGURE 32) supposes that near the caudal end of the pubo-ischiadic plate of the ancestral rhipidist two rapidly growing and at first subequal processes developed: the first grew medially from the acetabulum, forming the ischium; the second grew dorsolaterally from the acetabulum, forming the ilium. Both these processes were analogous with such apophyses as the great trochanter of the femur, or the greater tuberosity of the humerus, and their sutural contacts, together with that of the remaining "shaft" of the bone (= pubis) all met in the acetabular depression. As the acetabulum travelled onto the lateral surface of the pubo-ischiadic plate, it carried with it all three of its primary contacts (with the pubis in front, the iliac epiphysis above, and the ischial epiphysis posteriorly). In other words, the sutures stayed in the acetabulum and as the ilium and ischium (which were, so to speak, offsets from the parent pelvic rod) grew larger, the areas bounding the iliac and ischial portions of the acetabulum grew larger at the expense of their parent; the sutural contacts merely emphasized the triradiate character which had been potentially present as soon as the iliac and ischial apophyses developed.

DISCUSSION AND SUMMARY

The most general conclusion in Part I is that the already known groups of Palaeozoic chordates when considered collectively afford the broad outline of the evolution of the girdles and paired appendages, just as they do of the evolution of the oralo-branchial skeleton, dentigerous jaw

plates, circumorbital, temporal, opercular, and skull roof bones, as well as of the endocranium. This conception does not neglect the phylogenetic and taxonomic results already worked out by specialists in each group. On the contrary, the degree of validity of the present conclusions depends upon the accuracy of our evaluation of those results. Thus the phylogenetic-taxonomic discovery by Heintz (1931a) that the, at first sight, highly specialized, large-spined acanthaspids stand at or at least quite close to the base of the arthrodiran stem, supports our general impression from much other material that not a few forms which have been used by systematists as the bases for "new" subclasses, orders, suborders, families, etc., eventually turn out to be the possessors of what we may perhaps paradoxically call "primitive or stem specializations."

Secondly, the consistent application of the hypothesis of Homer Smith that the well-armored state of Palaeozoic agnathous and gnathostomal fishes may be another relatively primitive condition, has led to conclusions which may prove somewhat shocking to confirmed taxonomists of the modern "splitter" type. Here are to be listed the following ideas:

(1) That the pteraspid ostracoderms, with well-armored cephalothorax, instead of being aberrantly specialized, are really amazingly primitive fishes; that from their cephalo-thoracic shield, or from something that was fundamentally like it, were derived the dermocranium and the dermal pectoral girdle of all later fishes (p. 276).

(2) In the evolution of pectoral fins the exoskeletal parts of the primitive fin projections, including spines and dermal rays of various types, to some extent preceded the development of radial rods; and the condition in *Cladoselache*, in which the radials extend almost to the outer edge of the fin web, is hardly more primitive than it is in modern rays (p. 282).

(3) That the "tribasic" pectoral, with fan-like base, already recorded in representatives of the acanthodians, stegoselachians, and primitive elasmobranchs, is the primitive type for all gnathostome fishes, including the rhipidists, and thus eventually for tetrapods (p. 283).

(4) That the so-called cartilaginous shoulder-girdle is not the equivalent of the transverse septum of cephalaspids but merely a medial process of the basal cartilages of the pectoral fin, just as the pelvic rods represent medial processes from the base of the pelvic fin (pp. 283, 284).

(5) That the conical form of both the pectoral and pelvic cartilages was due to their being surrounded by concentric metameric muscles (p. 282).

(6) While the endoskeleton of the pectoral girdle is an ingrowth from the base of the fin, the dermal girdle is a remnant of the thoracic armor, and the progressive reduction of the carapace and plastron of Arthrodira,

as described by Heintz, affords at least a broad parallel to the way in which the dermal girdles of acanthodians and of Osteichthyes probably arose (p. 278).

(7) In reviewing the types of paired-fin skeletons found among the elasmobranchs it was noted that both extremes, the orthostichous or long-based type with but slight axillary incisure, and the mesorhachic or narrow-based type with deep axial incisure and jointed central axis, are found within the limits of this one class, whereas among the teleostomatous fishes the mesorhachic and rhipidistial type occurs only among the Choanata (Crossopterygii plus Dipnoi), while the orthostichous form is limited to the pelvic fins of the Chondrostei (p. 285).

(8) Nevertheless it was also suggested that the rhipidistial pectoral of *Eusthenopteron* may have been derived from a primitive tribasic, multiradial type by the loss of the propterygium and mesopterygium and by the virtual capture of the mesopterygial radials by the dominant metapterygial, the latter forming the "mesomeres" A, B, C, D, etc. (p. 287).

(9) In Part II the new restoration of the skeleton of *Eusthenopteron*, based on a considerable range of material, suggests a swift-darting, predaceous fish somewhat salmon-like but with a *Polypterus*-like head, very large triple caudal fin with rod-like, not fan-like, hypurals; two paddle-like dorsal fins and a paddle-like anal fin; pectoral and pelvic paddles essentially similar but pectorals larger than pelvics; both with stout fleshy lobe containing three or four mesomeres and as many radials, the latter being directed toward the convex anterior or preaxial border (p. 305).

(10) With regard to the possible derivation of *Eusthenopteron* it is assumed that it was at least a structural derivative of *Osteolepis*, which was the more primitive of the two in at least seven important features.

(11) The nearest relative of *Eusthenopteron* is the more or less contemporary genus *Tristichopterus*, which was, however, less advanced in the development of the triple caudal fin (p. 309).

(12) The claims of *Eusthenopteron* to be considered ancestral to the coelacanths are regarded as well founded; but we should not on that account exclude it from possible ancestry also to the tetrapod stem (p. 310).

(13) The presence of specialized, almost limb-like second dorsal and anal fins in *Eusthenopteron* might be regarded by many authors as a sign of aberrant specialization which would debar such a form from ancestry to the tetrapods, since no known tetrapod bears any traces of such structures. The present authors, on the other hand, accepting the evidence that, in respect to the structural patterns of the skull, jaws, teeth,

vertebrae, girdles, and paired appendages, *Eusthenopteron* is well fitted to give rise to the tetrapods, suppose also that during the transitional, incipiently amphibious stage, the emphasis of selection was shifted from the median fins to the paired fins, with resultant diminution and final elimination of the former, as shown by Dollo to have been the course of events in the phylogeny of the Dipnoi (p. 327).

(14) In Part III the authors return to their attack upon the problem of the detailed changes in the skeleton of the paired paddles during the period of transformation from a *Eusthenopteron*-like stage to the primitive tetrapod stage. The construction of a large flexible model has made it possible to pose the *Eusthenopteron* pectoral paddle in four successive positions: (1) the "shark position," with the preaxial border in a nearly horizontal position; (2) the "*Eusthenopteron* position," with the preaxial border directed downward; (3) the "*Polypterus* and *Ceratodus* position," with the preaxial border twisted into a dorsal position; (4) the "tetrapod position," derived from (3) by (*a*) bending the distal part of the fleshy lobe and fin outward to form an elbow joint, (*b*) twisting the distal half so that the preaxial border is brought around toward the midline of the body, (*c*) bending the distal half on its future extensor side to form a wrist (p. 318).

(15) The authors confirm the results summarized by Romer and Byrne (1931) which mean in essence that the flexor surface of the pectoral appendage of tetrapods was derived from that surface of the paddle in *Eusthenopteron* which was on the lateral or outer surface when the preaxial margin was dorsal in position (p. 314).

(16) They also agree with Romer that the elbow bend brought this lateral flexor surface so that it faced downward; when the digits developed, at a later period, the first digit was thus carried around to the medial side and the footprint faced forward (p. 314).

(17) They disagree with Romer only in the identification of the preaxial border in terms of the bones of the forearm, since they equate the tetrapod radius with the first paramere or radial (a), whereas Romer equates it with the second mesomere (B). They explain this contradiction as being the result of Romer's forgetting to twist the *Eusthenopteron* fin on its glenoid socket so as to bring the first radial (a) from the ventral (where it is usually found) to the dorsal position, as it is in *Polypterus* and *Ceratodus* (p. 319).

(18) It is suggested that as the elbow and wrist bends were being established differential growth occurred among the various bones; the rapid elongation of the second mesomere (B) caused the bones distal to

it (C, D, E, b, c) to be swung over toward the preaxial side so that they were crowded against the enlarged radial (a) (p. 322).

(19) The record of the foregoing change is to be found in the hitherto unexplained fact that in the earliest tetrapods all the carpal elements (except those that are in line with the radius) converge toward the postaxial ulna (p. 326).

(20) The known bones in the pectoral paddle of *Eusthenopteron* equal, or nearly equal, in number the carpal bones of the primitive tetrapod but there are not nearly enough bones in either *Eusthenopteron* or *Sauripterus* to give rise to the carpals plus metacarpals, plus phalanges of primitive pentadactylate tetrapods (p. 322).

(21) Partly in order to account for the larger number of bones in the primitive tetrapod manus, Holmgren (1939: 95–102) assumes that the tetrapod must have been derived not from *Eusthenopteron* but from a shark-like predecessor with many branches in the intermedium-centrale complex. According to this concept the *Eusthenopteron* type of fin has suffered reduction in the number of branches in the intermedium region (our radial b) which debars it from ancestry to the tetrapods. We, on the contrary, assuming as valid the evidence that the tetrapod skull has been derived from a rhipidist stage, see no necessity for denying to the pro-tetrapod descendants of the *Eusthenopteron* stock the ability both to produce new centres of ossification and to reduce and eliminate old ones (pp. 322, 323).

(22) The demand that the remote pro-tetrapod ancestors must already show the same or a greater number of bones in the pectoral paddles as do their highly evolved descendants appears to us as an excellent example of unwarranted extrapolation; it seems indeed like a survivor of the discredited *emboîtement* theory; but we ascribe it to the prevalent fashion of over-extending the doctrine of irreversibility of evolution (p. 343).

(23) While admitting that the rhipidist paddle eventually arose from a shark-like type with a four-jointed mesomeral metapterygium and numerous radials, the evidence suggests to us that during the post-rhipidist, pro-tetrapod stage there arose a digitiferous zone along the, by that time, curved mesomeral border, from which all the numbered digits (I–V), including the carpals, metacarpals, and phalanges, budded off. These extra buds, like the postaxial radials of dipnoans, arose *de novo* from the distal extremities or postaxial borders of mesomeres E, D, C, giving rise respectively to carpals, metacarpals, and digits I, II, III, IV, V. The radial series (a, a_1, a_2) was not one of the numbered digits but gave rise to the radiale, "y" centrale, and "prepollex." Nor should

we forget the diminution and eventual elimination of preaxial radials b and c, and their distal buds (pp. 322, 327).

(24) In the pro-tetrapods the above named process of budding gave rise at first to the phalangeal formula, 2, 2, 3, 2, 2–0 which is retained in early Amphibia; a somewhat later phase of the same process gave rise to the formula, 2, 3, 4, 5, 3, of primitive reptiles. The mammalian formula, as shown by Broom, arose by reduction and eventual loss of one phalanx in the third and of two in the fourth digit.

(25) That the digits (including the carpals and metacarpals) of tetrapods are *directly* derivable from the radial rods of sharks appears to us improbable, partly from the fact that the digital muscles of the more primitive tetrapods are fan-like subdivisions and extensions of muscle masses that spring from the humerus, forearm, and carpus respectively, much as they do in *Polypterus*, and that comparison with shark muscles can best be effected through the intervention of a *Polypterus*-like or rhipidistian stage.

(26) While the digitiferous zone was giving off the future carpals, metacarpals, and phalanges, the flexor and extensor muscle masses were developing peripherally, subdividing into a fan with sinuate digitate border. Meanwhile the dermal rays were fading away much as they did in the later dipnoans (pp. 320, 327).

(27) We endorse the conclusion of Romer that in the pelvic limb there was at first no twisting, merely a bending at the future knee and a forward-drawing of the knee, keeping the mesomeral axis on the medial border (pp. 329, 330).

(28) Although the total number of bones in the rhipidist pelvic paddle is equal, or nearly equal, to that in the hind limb of tetrapods, after excluding the metatarsals and phalanges, yet there is good reason for inferring that two of the rhipidist radials (b, c) and their distal buds were eliminated, while the digitiferous zone along the distal postaxial border of the mesomeral axis gave rise to all the tetrapod tarsals, metatarsals, and digits I–V (p. 329).

(29) The existence of a tibial series of several ossicles distal to the tibia (tibiale, "y," and "prehallux") has been confirmed in *Trematops* (B. Schaeffer) (p. 329).

(30) All the numbered digits (I–V) converge toward the postaxial or mesomeral stem, as in the pectoral paddle (p. 329).

(31) We may therefore assume that just as in the pectoral paddle the postaxial mesomeral series were swung over against the preaxial side, while the digitiferous zone arose on that distal postaxial part which, as

the dermal rays dwindled, was coming directly into contact with the substrate (p. 329).

(32) In Part IV the following new theory is proposed, relating to the origin of the tetrapod pelvis. It is assumed that the pelvic bones of osteichthyan fishes arose as a core to an inwardly-growing cone of metameric muscles that were wrapped around the base of the pelvic fins. By the time of the ancestral rhipidists these bony cores had already begun to grow forward toward the midline and had produced the anlage of the future os innominatum. In *Eusthenopteron* each os innominatum consisted of a rather long, somewhat decurved blade, pointed in front, with a convex anterodorsal rim and a slightly convex lateral or abductor surface. The acetabulum at the posterior end of the innominate bar faced posteriorly and slightly laterally. Above the acetabulum was a low backwardly-directed apophysis, which is assumed to be the anlage of the future ilium (p. 333).

It is further assumed that in young individuals this iliac apophysis formed an epiphysis on the dorsoposterior border of the acetabulum and that another epiphysis immediately medioposterior to the first was the anlage of the future ischium. The parent mass of the innominate bone gave rise to the pubis. As the paddles changed into limbs and the future femora (mesomere A) were drawn outward and forward, the acetabula shifted with the femora to the lateral surface of the pubes. Further development in the same direction brought a great hypertrophy of the two epiphyseal apophyses; the ilium growing dorsad to support the increasing extensor femoris, the ischium growing caudally to support the growing adductor mass. In this way the hitherto puzzling triradiate suture of the tetrapod pelvis finds a reasonable explanation (p. 334).

(33) The foregoing theories of origin of the paired limbs and girdles differ from many of those hitherto put forward in the following general characteristics:

(*a*) As far as possible they attempt to trace the evolution of the vertebrate paired appendages by the application of well-tested morphological precedents to known fossil forms. Thus they try to avoid the fallacy of "*ignotum per ignotius*," which seems to be involved when the sequence afforded by known Agnatha, Placodermi, Crossopterygii, Labyrinthodontia, Amphibia, is set aside, because, it is alleged, each known representative of these groups is "aberrantly specialized" in this or that particular feature. *Sauripterus*, for example, has been rejected as a near-ancestor to the tetrapods because its pectoral paddle is not sufficiently shark-like.

(*b*) The habit of inventing new hypothetical orders rather than of

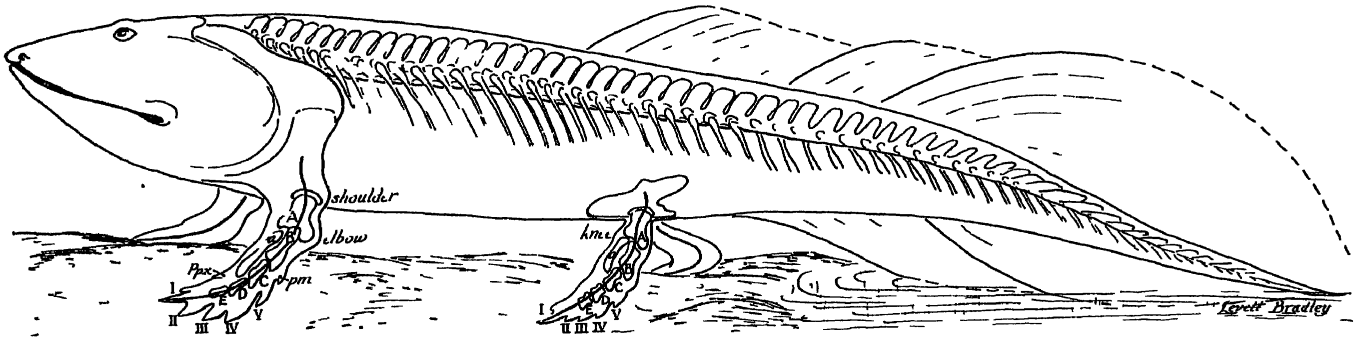

FIGURE 34. Suggested protetrapod stage between rhipidist and primitive labyrinthodont.

making full use of those which we have has arisen, we maintain, through a misreading of the doctrine of the irreversibility of evolution and through a tendency to revert to the *emboîtement* theory and to expect remote ancestors to display only those specializations which are found in greater degree in their descendants. We, on the other hand, maintain that the wholly new habit of using the paired appendages to support the weight of the body on land became possible only through a drastic revolution in construction, with the loss of many ancient uniformities and the rise of such new and unexpected entities as the digitiferous zone on the margin of the rhipidist "fleshy lobe."

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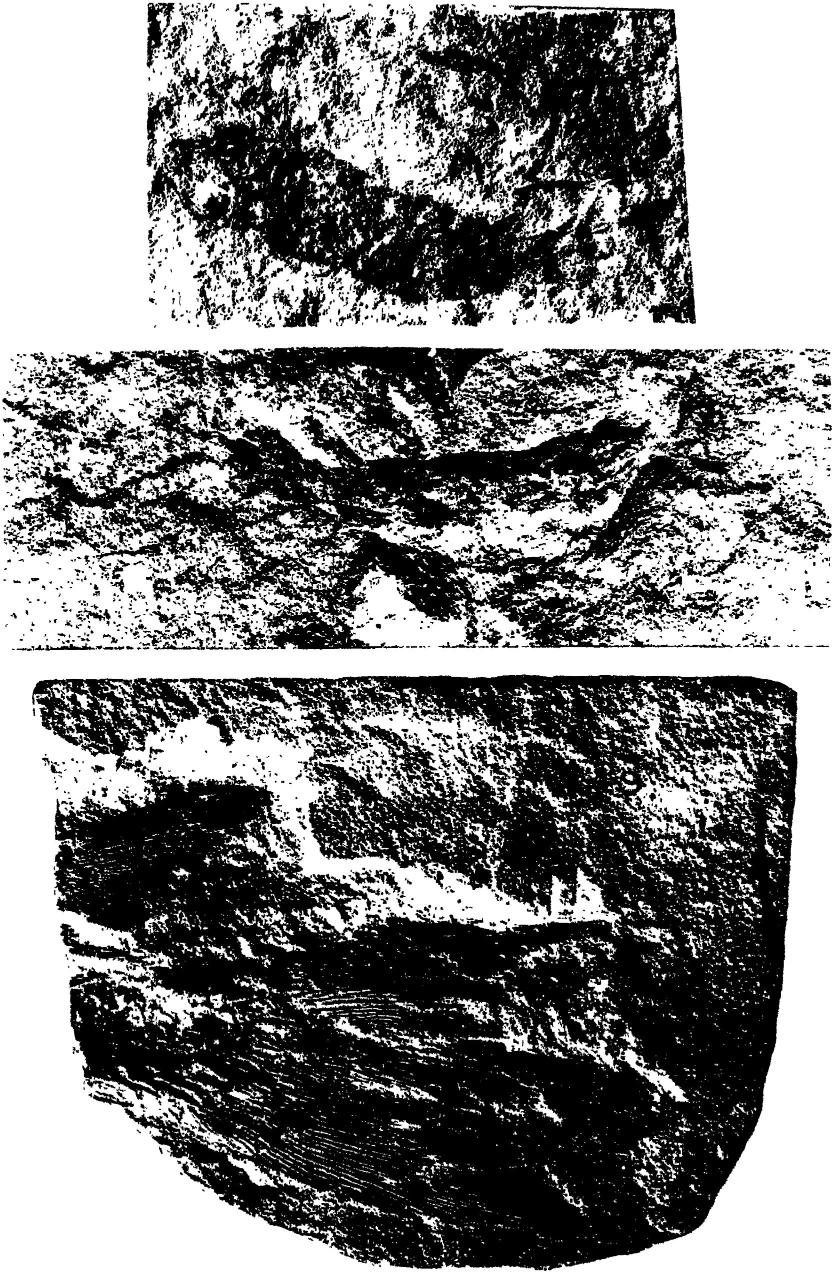
EXPLANATION OF PLATES

PLATE 1

FIGURE 1. Smallest *Eusthenopteron* (A.M. 7687). Total length, 44 mm.

FIGURE 2. Post-larval specimen (A.M. 7650). Total length, 64 mm.

FIGURE 3. Caudal fin of young specimen (A.M. 7649).



Gregory and Raven: *EUSTHENOPTERON*

Gregory and Raven *EUSTHENOPTERON*

PLATE 2

Vertebral column of *Eusthenopteron* (A M 7653) Upper half × ⅔

PLATE 3

Vertebral column of *Eusthenopteron* (A.M. 7653). Lower half. × ⅔.

Gregory and Raven: *EUSTHENOPTERON*

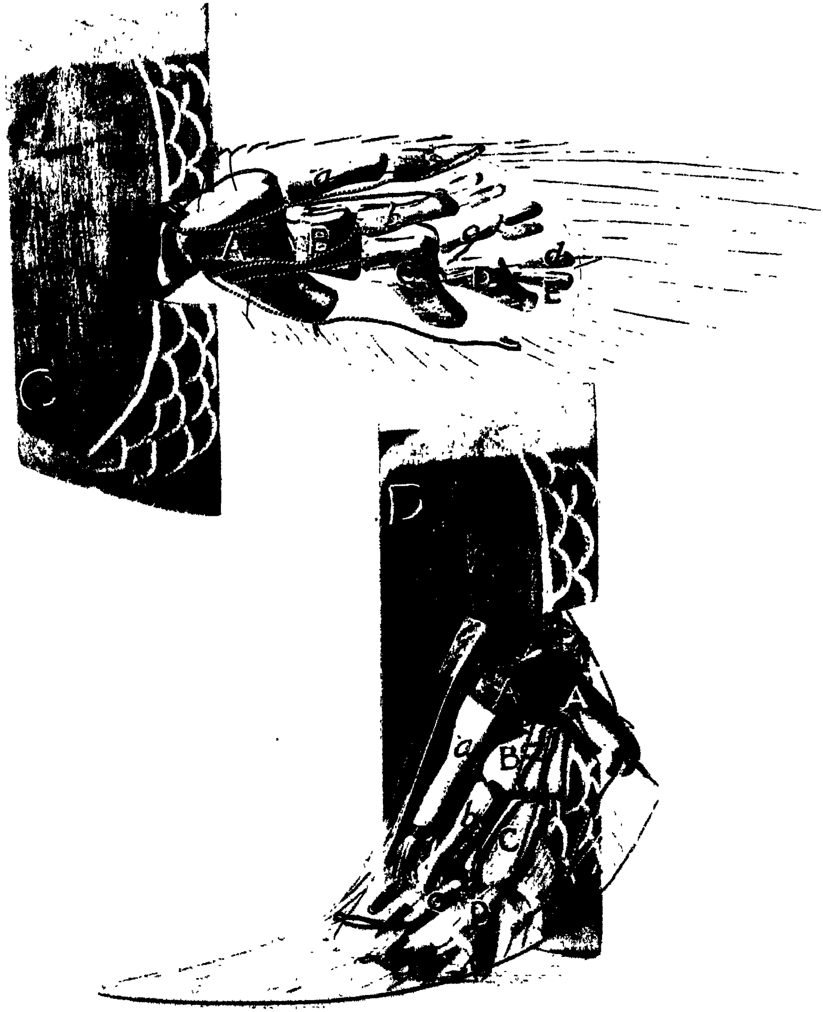
Gregory and Raven *EUSTHENOPTERON*

PLATE 4

Enlarged model of *Eusthenopteron* fin A Shark position B *Eusthenopteron* position

PLATE 5

Enlarged model of *Eusthenopteron* fin. C. *Polypterus* and *Ceratodus* position. D. Tetrapod position.



GREGORY AND RAVEN: *EUSTHENOPTERON*

Annals of the New York Academy of Sciences
Volume XLII, Art. 4. Pages 361–490
January 31, 1942

INTELLIGENCE IN MENTAL DISORDER*

By

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*From the Worcester State Hospital. We are grateful to the many members of the Psychology and Biometrics Departments who over a period of years contributed to the study. We are grateful, too, for the considerable aid, especially in the preparation of the manuscript, which was obtained from the Works Projects Administration, Project Nos. 17026 and 20787.

Publication made possible through a grant from the income of the Permanent Fund.

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INTRODUCTION

The use of psychometric methods in connection with clinical and research work in mental disorders, while increasing in extent, is greatly hampered because there have been insufficient data with regard to any one of these methods to permit interpretation of such results with any degree of assurance. In dealing with abnormal persons, a number of questions arise which cannot be answered by the accumulated data on children on whom most tests have been standardized, or even by data on normal adults when these are available, but which must be solved, at least in a general way, if test results are to be meaningful in any individual case.

In spite of the many and legitimate objections which can be raised with respect to the Stanford-Binet in use with adults, it has generally been the test of choice in the clinical situation because of the variety of tasks involved and the insight which it can afford to a trained examiner. It is particularly the trained and sensitive examiner, however, who has most appreciated the need for data which would make it possible to place an individual with regard to his own psychiatric classification as well as with regard to normal standards. Further, there have been few data on the relative significance of the individual items as indicators of departure from normality.

In an attempt to find an answer to some of these problems, at least in terms of a first approximation, we embarked some years ago upon a study, concerned with groups rather than with individuals, the results of which are reported here. Our research includes an attempt to determine (*a*) the general test level of various diagnostic groups, and (*b*) the relative performance of different groups on different types of tests (profiles). The latter type of analysis leads to the very fundamental question of whether there is any relation between functional change and type of disorder. It is important to investigate fully the possibility of trends of cognitive change in any diagnostic group before the performance of an individual member of the group can be evaluated. If trends exist and can be discovered, the next logical step is the investigation of the significance of the presence or absence of conformity of the individual patient to the group.

Once the performance in various groups has been established, it is possible to compare them with a normal group and with each other, as we have done here. These comparisons are valid in so far as there is no selective factor of importance other than that of the diagnosis; the groups

are relatively equivalent so far as any other factors affecting mental level are concerned. For all practical purposes it is necessary to demonstrate only that the groups are drawn from the same general population, *i. e.*, the factors of age, education and social level must be considered; the age distributions in the different psychoses must be kept in mind, also, as well as the varying effects of age on educational level.

A consideration of great importance, and one frequently disregarded, is whether or not all tests of psychotics can legitimately be grouped together, even within one diagnostic classification. When the problem at hand is simply the determination of what such a group, taken as a whole, does on examination, it is valid to use any results that can be obtained. But where the objective is the comparison of various groups the situation is somewhat different.

One of the first requisites in setting up any problem is a careful specification of the population, and in this investigation we were faced immediately with the question of whether to analyze the performances of our total psychotic groups or whether to split these into "representative" (R) and "non-representative" (n–R) groups and deal separately with each. These terms are used at the Worcester State Hospital, as elsewhere, to distinguish between examinations for which, on the one hand, the subject was sufficiently accessible and cooperative to make the examiner feel that the obtained results gave a reasonably accurate picture of the patient's functional level at the general period of the test, and which, on the other, the examiner felt did not do justice to the subject's ability*.

On the face of it, it would seem that to compare a psychotic group with an "unselected" normal group, we must use all the psychotic material available. However, although all of the subjects in the normal group cooperated freely, so that in each instance we were justified in considering that our results were a close approximation to the capacity, or at least the ability, of that subject†, not all of the patients would or could cooperate. In only a certain proportion of these cases, then, did we feel that we had an adequate measure of the subject's ability at the time. Scores are affected by cooperation to an unknown extent, but cooperation is itself often related to the severity of the psychosis. If we include all cases, we have in many of the psychotic subjects a factor not present in any of the normals. If we exclude the non-cooperative, we exclude a considerable number of the severest cases, and hence somewhat prejudice our results in favor of the psychotics. Some preliminary investigation

*The criteria by which this distinction is made are discussed more fully on pages 378–380
†For a discussion of capacity, ability, and achievement in psychosis, *cf.* Shakow & Huston (1936: 91)

of the problem of representativeness was thus indicated as necessary. The results of a study of this problem are reported on pages 378–395.

In comparing the profiles of two diagnostic groups, recourse is sometimes had to matching for intellectual level and any differences found in specific performances are then considered a direct result of the disease process and not a reflection of the general lowering. This procedure although valuable for certain purposes, is, however, open to serious objection. Though we know as yet comparatively little about the intra-individual relations of different functions, it is fairly clear that the intercorrelation of functions is not the same at all levels of general intelligence. In most instances of psychosis we do find changes in cognitive functions, generally a lowering of them. If, then, we are comparing the psychotic and non-psychotic, either we must take only those psychotics who do not show a lowering or whose original level was so high that deterioration does not bring them below average or we must compare psychotics and dull or feebleminded non-psychotics. In each instance we have a different selective factor in the two groups. It is, of course, entirely legitimate and illuminating to compare the feebleminded with psychotics in this fashion, but we cannot argue from this to any conclusions with respect to normal-psychotic comparisons. Comparing matched pairs from two psychotic groups is subject to the same criticism which can be applied to psychotic-normal comparisons—different types of psychosis may affect general intellectual functioning to different degrees, and we are in danger of comparing, for instance, the upper third of one diagnostic group with the middle or lower third of another.

We have studied not only the profiles, but also the general level of these groups. Binet and Simon (1916) early observed, "It is almost an absolute rule that the insane undergo a lowering of level". Previous work by others relates for the most part to comparisons between and among various diagnostic groups; there has not heretofore been available adequate material from normal adults for detailed comparisons. Hart and Spearman (1914) in a pioneer correlational study found in various types of psychoses (their numbers ran from 1 to 10, however) little damage of specific functions, but a marked general lowering of intellectual level. Rouvroy (1936) has discussed studies on mental tests with psychopaths in a critical paper which is not readily available. He concludes that we have no instrument adequate to determine accurately the quantitative and qualitative changes in intelligence which have been demonstrated to occur with the disordered. He points out quite correctly that the total scores of different individuals on an omnibus test may be the same, and yet may indicate quite different things, the ele-

ments going into them being disproportionately present. He considers two chief classes of items: automatised or habitual reactions, *e.g.*, vocabulary, which he believes scarcely affected in the psychotic, and the ability to cope with new situations, which he believes to be usually affected. Hunt (1936) covers most of the psychometric material for the period through 1934 in his inclusive survey of psychological work with abnormal subjects. His review gives a rather comprehensive general picture of what had been done to the date mentioned and a further survey need not be given here. For one reason or another, very few reports contain only material directly comparable to that of the present study. All relevant material from other investigations will therefore be discussed in connection with the presentation of particular sections of our own results. One general difference should be noted. In previous studies, "representativeness" of the test results has, as a rule, been considered only indirectly; usually, if the examiner could obtain any results at all they were used. Comparisons between other studies and the present one are therefore almost always between groups including both representative and non-representative examinations in our usage, and our representative groups.

Our material will be presented for consideration under three general headings: (1) comparisons of representative and non-representative test performances within the various diagnostic groups; (2) comparisons between our sample of a state hospital population, grouped by diagnosis, and a normal group and (3) comparisons between and among various diagnostic groups.

DATA AND METHODS OF ANALYSIS

Description of the Sample

Our material consists of the results of Stanford-Binet (1916) examinations given to 827 patients at the Worcester State Hospital during the years 1929 to 1933. These comprise practically all of the Stanford-Binet examinations in this period with the exception of those given to patients who either had had a previous Stanford-Binet, or whose examination data did not permit practically complete item analysis. Throughout the compilation, cases were discarded whenever any serious question arose as to the validity of the data, as occasionally happened for diverse reasons. The Stanford-Binet as a rule is not given when there is a language handicap but among the cases presented here are included a few with moderate language difficulty and a few illiterates.

Except for certain of the dementia praecox cases, the staff diagnosis

at the time of the test is the one used. Some of the dementia praecox cases, on special research, had been very extensively studied, and classified more rigidly than others. These others were reconsidered in order to make more certain of a common classification.

The diagnostic criteria are the conventional ones and the likelihood of diagnostic error is probably not greater than at any other hospital of good standing, but cases in which staff disagreement on diagnosis was particularly marked are not included. There is certainly some overlapping of diagnosis between groups generally, although the possibility of error is greater in some groups than in others, *e.g.*, in the distinction between the two types of psychopathic personalities*.

Each diagnostic group was subdivided into two groups according to whether the Stanford-Binet was considered representative or not. Factors affecting representativeness, as the term is used by us, are: effort, interest, confidence, temporary psychotic episodes, or emotional disturbances, physical illness or poor test conditions. General psychotic state, permanent physical disability, age, or language handicap do not affect the rating on representativeness. This distinction was not introduced at the hospital until 1930, so that for the earlier examination it was necessary to make the rating from the examiner's description of the patient's behavior which was, in practically all cases, available in the report. When this could not be done the case was omitted. Comparisons between diagnostic groups and between these and normal subjects are made with representative groups. The non-representative groups are used only for comparisons with representative groups of the same diagnostic classifications and only when they are of sufficient size for useful statistical comparison.

TABLE 1 gives the number of cases by sex for each diagnostic group further subdivided into the representative (R) and non-representative (n–R) classifications.

The selection of groups from our total hospital population needs discussion since not all patients admitted to the hospital are referred for psychometric examination. Cases in which there is any question of feeblemindedness, cases sent by the court for observation and diagnosis, and all special research cases are almost always referred. For the rest, the matter is usually one for the decision of the psychiatrist in charge of

*It should be noted that grouping by diagnosis imposes certain limitations upon the data at the outset which must be clearly understood. Age ranges, for example, are not the same for all psychoses because of factors inherent in the psychosis itself. In some psychoses, the percent of non-representative tests will be much greater than others. Furthermore, while the diagnostic criteria are by no means exact in any instance, they are much clearer in some than they are in others.

TABLE 1

NUMBER OF CASES IN THE DIAGNOSTIC GROUPS

	Representative (R)			Non-representative (n-R)		
	M.	F.	Total	M.	F.	Total
General Paresis (GP)*	24	11	35	20	4	24
Chronic Alcoholism with Psychosis (CA+)	30	0	30	10	2	12
Chronic Alcoholism without Psychosis (CA−)	7	5	12	2	0	2
Acute Alcoholic Psychosis (AA)	16	1	17	6	0	6
Feeblemindedness with Psychosis (FM+)	35	25	60	10	15	25
Feeblemindedness without Psychosis (FM−)	14	13	27	3	7	10
Paranoid D. P. (DPP)	45	13	58	25	6	31
Hebephrenic D. P. (DPH)	27	5	32	24	5	29
Catatonic D. P. (DPC)	21	9	30	24	4	28
Simple D. P. (DPS)	19	3	22	7	0	7
Unclassified D. P. (DPU)	32	6	38	19	6	25
Manic-Depressive (MD)	13	6	19	9	9	18
Psychopathic Personality with Psychosis (PP+)	5	17	22	5	9	14
Psychopathic Personality without Psychosis (PP−)	12	9	21	3	1	4
Paranoid Condition (PC)	15	7	22	5	4	9
Psychoneurosis (PN)	15	21	36	4	8	12
Without Psychosis (WP)	59	13	72	12	6	18
	389	161	553	188	86	274

*These groups will occasionally be designated by the respective symbols in parentheses.

the case and the number and types of cases referred vary somewhat from one psychiatrist to another†.

Comparing the several diagnostic groups—representative and non-representative—to the corresponding groups of hospital first admissions for 1929, 1930, and 1931 in which years the bulk of our cases fall, it appears that our groups average 0.3 to 8.5 years younger than these first admissions. The greatest differences are in the general paresis, without psychosis and paranoid condition groups. It is undoubtedly the case that the much older patients would be less likely to be referred for psy-

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some value for comparative purposes.

chometric examination. Statistics for comparing education and occupational levels of our groups with the total hospital population are not available. The somewhat younger age level in some groups would tend, in all probabilty, to make our groups slightly higher, if anything, on psychometric performance. This would mean that any normal-psychopathic discrepancies which appear in this analysis will be less than would be found if the total hospital group had been available. There seems no reason for believing any diagnostic group to be very differently selected from any other with respect to the total hospital population of that diagnosis (although undoubtedly the relative numbers of each group referred for psychometric examination vary) so that the diagnostic

TABLE 2

DATA ON AGE, EDUCATION, AND OCCUPATION OF PATIENT POPULATION

		N	Range	Mean & S.E.	S.D. & S.E.
Age	R	553	10–68	31.4±0.5	11.1±0.3
	n–R	274	11–65	31.1±0.6	10.4±0.5
	Total	827	10–68	31.3±0.4	10.9±0.3
Ed	R	534	0–19	7.9±0.2	3.4±0.1
	n–R	267	0–17	7.8±0.2	3.4±0.2
	Total	801	0–19	7.9±0.1	3.4±0.1

OCCUPATION BY TAUSSIG CLASSES*

	R		n–R		Total	
	N	%	N	%	N	%
I Professional	14	4	6	2	20	3
II Semi-professional and Business	78	20	49	17	127	19
III Skilled labor	90	24	57	20	147	22
IV Semi-skilled labor	129	34	112	39	241	36
V Unskilled labor	68	18	62	22	130	20
	379		286		665	

UNCLASSIFIED

School	44
Housewives**	18
No occupation	78
Occupation unknown***	22
	162

*Where several occupations were listed, the highest was rated.

**Occupation of housewives before marriage was usually known, in which case ratings were made on this basis. Most of the women are classified in groups II and IV.

***This may include some who are more properly classified under "no occupation."

groups may legitimately be compared with each other. TABLE 2 gives the data for age, education*, and occupation of total representative, total non-representative, and total hospital group. There were 20 patients below 14 years of age. These data for the separate diagnostic groups are given in the appendix (TABLES 29 to 31).

In the first tabulations, results for male and female patients were kept separate. Although in a few instances, in the smaller groups, there were differences of some degree, on the whole the sexes gave very similar results. As a result of this and the fact that in the normal group no significant sex differences were found, the sexes have been combined and only the total group determinations used in the present analysis.

*The figures for education are number of years of schooling completed, based on the best information obtainable.

TABLE 3

DATA ON HOSPITAL AGE* (IN MONTHS) OF THE PATIENT POPULATION AT THE TIME OF THE EXAMINATION

Diagnosis	Representative					Non-representative				
	N	Range	Mean	Omitted Cases**		N	Range	Mean	Omitted Cases	
				N	Range				N	Range
General Paresis	33	.5-15	2.3	2	58.5 75.5	21	.5 5.5	1.5	1	37
Chr. Alc. with Psy.	26	.5 5.5	1.3	3	13.5 19.0	11	.5-2	1.1	1	38
Chr. Alc. without Psy.	11	.5-1.0	.8	1	16	7	.5-1	.8	1	18
Acute Alc. Psy.	15	.5-1.5	.8	1	72.5	...	....	.	.	. . .
Feeble. with Psy.	57	.5-14.5	1.2	3	19.5 293.5	25	.5 6.5	1.0	0	....
Feeble. without Psy.	21	.5 2.5	.8	2	32.5 39.5	9	.5 1.5	.7	0	. .
Paranoid DP.	48	.5 30	2.8	7	57.5 183.5	29	.5 9	1.9	2	53.5–62
Hebephrenic DP	28	.5 18	3.1	1	34 117	23	.5 15	4.0	6	39.5–132.5
Catatonic DP.	30	.5 14.5	2.0	1	177	27	.5 19	3.6	1	25.5
Simple DP.	19	.5 11	1.3	2	31 138	3	.5 1	.7	0	..
Unclassified DP	35	.5-15	2.6	2	136 251	22	.5 25	3.0	3	83–96.5
Total DP.	161	.5–30	2.5	17	31 251	101	.5 21.5	3.1	11	25.5–132.5
Manic Depressive.	18	.5–7	1.7	1	39.5	16	.5 10.5	2.0	2	40.5–72
Psy. Pers. with Psy.	21	.5-2.5	.9	2	24-27	14	.5 1.5	.7	0	..
Psy. Pers. without Psy.	20	.5–7.5	1.1	0	....	4	.5	.5	0	.
Paranoid Condition	21	.5-1.5	.8	1	107.5	8	.5-1.0	.9	1	11
Psychoneurosis.	32	.5–4	.9	2	9-11	12	.5–3	1.0	0	....
Without Psy.	67	.5	.7	1	18.5	18	.5–2.5	.8	0	.

*Hospital age is the period beginning at time of first hospitalization.
**In all but a few of the group there were some cases with hospital ages falling quite a distance outside of the distribution of the great majority of the cases. These were omitted, because of their distorting effect, in computing the means for this table, but are given for purposes of completeness.

TABLE 3 gives the data on hospital age for the various groups, *i.e.*, the length of time elapsing between first hospitalization and the date of examination. It will be seen that with relatively few exceptions (*cf.* data in columns headed "omitted cases") our groups consist of patients who had been hospitalized for relatively short periods of time. The means in general run below 3 months.

Methods of Analysis

These data, for purposes of comparison, were analyzed in three major ways: *a*) by mean scores on total Stanford-Binet, on vocabulary, on digits forwards and on digits backwards; *b*) by the separate items of each age level according to the number passing or failing the specific item*; *c*) by the classifications into which the items fall**.

Differences in performance on individual items were analyzed by investigating the association between the number passing and failing the item in the compared groups. These chi-square computations were made in the usual way, except that, when, in any table, there were one or more cells with a frequency of less than 5, Yates' correction was applied (Simpson & Roe 1939: 296). This gives a smaller value for chi-square than would otherwise be obtained. In the smaller groups this was often necessary; it occurred also in the larger groups when fewer than 5 passed or failed any item, *i.e.*, at the upper and lower end of the scales, with some alternates which were rarely given, and also usually with item X-6, which also was rarely given. Graphs showing for a number of the groups the percent passing and failing each item are included in the comparisons.

For the sake of consistency in the matter of a criterion of significance, the values of D/σ_D obtained in comparing means are also expressed as values of P. We have followed the custom of interpreting a P of .02 or less as significant (the chances are 98 in 100 that the difference is not due to chance) and a P between .05 and .02 as of possible significance. This is, of course, less rigid in the case of the comparison of means than is the usual custom of considering only a D/σ_D of 3 or more as significant. Values of D/σ_D of 1.96 and 2.33 correspond to P values of .05 and .02 respectively. (So long as the meaning of the particular criterion used is clear, there is no reason why any one may not be selected. From a certain standpoint even these less stringent criteria are not entirely satis-

*All items below the basal age were considered as passed, all above the last year in which *any* tests were given, as failed. Omitted items are largely alternates and tests omitted on the few occasions when a short scale was given. It occasionally happened that only one test would be passed at a particular year level and that in the next only a few had been given. Those not given were counted as omitted, even though with normal subjects they would have been counted as failed. Percents were computed on the basis of the number actually attempting the item.

**No measures of scatter were included in the present investigation since separate studies on this subject were under way. One of these has already been published (Harris & Shakow 1938).

factory. Reference is to the fact that one may be led to neglect potentially important psychological trends which, for one reason or another, do not fall within the statistical limits set. For a study such as the present, however, which does not pretend to enter into the important problem of finer qualitative psychological differences, statistical limits seem the most reasonable.)

The third type of analysis is by the classification into which the item falls. Some exposition of the system followed is needed. We realize that any such classification is open to criticism from numerous angles. So much of coherence can, however, be gained in this way when a set of such diverse items as is involved in the Stanford is under question, that we feel that the advantages overweigh the disadvantages. After prolonged consideration the classification here presented was arrived at.

The items in the Stanford-Binet appear with few exceptions to fall, insofar as their dominant character is concerned, into two major classes: *learned material* and *thought*. In the former, the task is primarily the recall in the test situation of material learned at some time preceding, to a greater or lesser extent, the request for recall. In the latter, the task set is one which involves carrying through a train of ideas to a conclusion.

The *learned material* is of two primary types: *remote* and *immediate*. The first involves the recall of material learned through the course of the life experience which precedes the examination session. With few exceptions this material may legitimately be considered as overlearned. This group may be further subdivided into items involving *vocabulary* and *other* kinds of remotely learned material. Examples of the latter are "days of the week" and "coins." The second type of learned material—the *immediate*—involves the recall of material first presented to the subject directly preceding the requested recall. This type includes such tests as "digit repetition," both backwards and forwards, and "memory for thought passage."

The material involving *thought* falls into two primary types: *associative* and *conceptual*. The first is concerned with the kind of thinking in which the conclusions are arrived at by concrete associations. This type has been further subdivided into *immediate* and *sustained*. The former includes those instances of associative thinking in which the conclusion comes directly and involves few consecutive associative steps. In the latter the associative course is longer and requires keeping in mind at the same time a related series of associations. The second type of thinking —*conceptual*—involves the recognition and use of a general or abstract principle as a step in reaching the conclusion. Examples of *immediate associative thinking* are the comprehension items, and picture description

TABLE 4

CLASSIFICATION OF STANFORD-BINET ITEMS

Year Level	Remotely Learned —Vocabulary (LRV)	Remotely Learned —Other Types (LRO)	Immediately Learned (LI)	Associative Thinking— Immediate (TAI)	Associative Thinking— Sustained (TAS)	Conceptual Thinking (TC)
VI		1. R. & L. 3. 13 Pennies 5. Coins	6. Syll. (16)	2. Mut. Pic. 4. Compr.		
VII		1. Fingers 4. Bow Knot 7. Days week	3. 5DF 8. 3DB	2. Pic. Des.		5. Diff.
VIII	5. Defin. 6. Vocab. (20)	2. 20–0 7. Coins		3. Compr.	1. B & F	4. Simil.
IX		1. Date 7. Months	4. 4DB	3. Change	5. Sen. cons. 6. Rhymes	
X	1. Vocab. (30)		3. Designs 4. Rd. & Rep. 7. 6DF 8. Syll. (20)	5. Compr.		2. Absurd.
XII	1. Vocab. (40) 2. Abst. words		6. 5DB	7. Pic. Intp.	3. B & F 4. Diss. sent.	5. Fables 8. Simil.
XIV	1. Vocab. (50)		7. 7DF		5. Ar. reas. 6. Clock	2. Induct. 3. Pres. & King 4. Prob. Fact
XVI	1. Vocab. (65)		5. 6DB 7. Syll. (28)		4. Encl. box. 6. Code	2. Fables 3. Abs. words
XVIII	1. Vocab. (75)		3. 8DF 4. Thought 5. 7DB		2. Paper cut. 6. Ingenuity	

and interpretation. *Sustained associative thinking* is exemplified by "dissected sentences" and "ingenuity". "Differences" and "similarities", "absurdities", and "fables" are examples of *conceptual thinking.*

The various types of items together with the symbols used for them are given in the following tabulation:

I. *Learned material:*
  A. Remote
    1. Vocabulary....................LRV
    2. Other..........................LRO
  B. Immediate......................LI

II. *Thinking:*
  A. Associative
    1. Immediate....................TAI
    2. Sustained....................TAS
  B. Conceptual.................. ....TC

TABLE 4 gives the various test items from age VI through age XVIII classified according to this schema. A few items are omitted either because they do not fit into this classification or because they have been little used in our study.

In some instances additional data are available, *i.e.*, correlation coefficients. Since the groups are small, these have been converted to values of z, (Simpson & Roe 1939: 237) and these values are used in making the comparisons with the same criteria of significance as discussed above.

REPRESENTATIVE AND NON-REPRESENTATIVE GROUPS

The Concept of Representativeness

We present first the results of the comparison of representative and non-representative groups in the same diagnostic class. As has been stated earlier, this distinction is one that is made routinely at Worcester. Some of the factors affecting representativeness are under the partial control of the subject, *viz.*, effort, interest, and self-confidence. The others, almost entirely outside the subject's control, are of a relatively *temporary* kind: a psychotic episode (temporary manic, excited, or hallucinatory conditions), an emotional upset, physical handicap (loss of sensory aids such as glasses, etc.), passing physical illness (headache, etc.), fatigue, poor test conditions.

The complex of effort, interest, and self-confidence are summed up in the general term of co-operativeness and are given a letter rating from

A to E*; to be representative, a rating of A or B must be obtained. The influence of the other factors, except "psychotic episode," is not hard to evaluate.

It is obviously difficult to define and to set arbitrary limits for a psychotic episode and to distinguish between it and a psychotic state (a relatively permanent disturbed condition). What is necessary is for the examiner to have in mind the spirit and the purpose of making these judgments. Their primary purpose is to evaluate fairly the person's intellectual *capacity*. At the same time it is necessary to determine his functioning intelligence, *i.e.*, what he has to work with at the present time. If his performance today is, from all the evidence available with regard to his psychotic condition, the best he is likely to be able to achieve during the approximate period of the next few weeks, then in this respect the examination is representative. If the examiner, however, has any basis for feeling that the patient within a few days or a week or so would achieve a higher level of performance, he must consider the examination unrepresentative†. As has been stated, patients with permanent physical or serious language handicaps have been eliminated.

Studies in the psychomotor sphere (Shakow & Huston 1936; Huston, Shakow, & Riggs 1937) have brought out clearly that the attitude of the subject may profoundly influence his performance. We do not know of any searching investigation of this problem with regard to psychometric performance. It would seem likely that test performance would be affected, although it has been argued that psychometric results are not fundamentally affected by attitude. The question of how much or in what way is one which can be settled only by analysis of test results under varying conditions of cooperation on the subject's part. One needs to find out not only the degree of effect of attitude but also its selectivity, if any, on different types of test items. Too, it may be different with different types of psychosis. Such an analysis also makes possible a comparison of the differences of the effect of attitude and of

*A. The essential feature in the attitude designated by an *A* rating is that the patient must show an active interest in the tests themselves. Corollaries to this are that he should exert maximum effort in doing the tests and show interest in the results.

B. For this rating, the patient must give active and willing cooperation, and real effort, not because of a primary interest in the tests themselves, but because of some other factor, such as general friendliness or a desire to please the examiner.

C. Patients given this rating are docile and submissive but show no real interest; effort is perfunctory or spasmodic. Some urging is usually needed.

D. This rating is given to the patient who considers the examination a disagreeable task or an affront. He may be resentful, resistive, or surly. It is only after considerable urging and repeated questioning that any results are obtained.

E. Absolute refusal to cooperate results in this rating.

†If, in addition to being representative, there is no language or permanent physical handicap (*e.g.*, deafness), the patient is under 40 years of age, and the examiner feels that the psychometric results reflect not only present capacity but as high a level as the patient has ever achieved, the results are considered *optimal* as well as representative. This distinction concerns us here only insofar as it throws more light on the concept of representativeness.

that of psychosis (in the one case, representative *vs.* non-representative results within a psychosis, and in the other, representative results in a psychosis *vs.* normal results) on test performance*.

The Diagnostic Groups

In the following diagnoses, the non-representative subgroups were large enough for useful comparison: general paresis, feeblemindedness with psychosis, paranoid dementia praecox, hebephrenic dementia praecox, catatonic dementia praecox, unclassified dementia praecox, manic-depressive, psychopathic personality with psychosis, and without psychosis.

Data for all of these groups (N, Range, and Mean and Standard Deviation with their Standard Errors, for Stanford-Binet Score, in months, Vocabulary, in number of words passed, and Digits Forwards and Backwards, in terms of number repeated correctly) are given in the master tables (32 to 35) in the appendix. TABLE 5 gives comparative data for these results, as well as for age and education, in terms of the differences between the means and the standard error of this difference (mean of the non-representative minus the mean of the representative group). One asterisk, after the difference, indicates that the critical ratio is 1.96–2.33 (equivalent to $.05>P>.02$); two asterisks indicate that the critical ratio is greater than 2.33 ($P\leqq .02$).

Differences between the two sub-groups in each diagnosis in mean age are all very slight and none is significant. Differences in education are negligible except in the without psychosis groups, where the difference is of possible significance. In general the Taussing distributions (see TABLE 31 in appendix) are similar, the chief exception again being the without psychosis group. Except for this diagnostic group, we may reasonably assume that the subgroups are legitimately comparable in these descriptive characteristics.

That there is considerable overlapping in the distribution of the two members of each pair for each variable is obvious from the table, although, with three minor exceptions in which the differences are very slight, the means of the non-representative groups are lower than for

*Certainly the judgment of representativeness is to a large extent a subjective one, but in the case of skilled examiners should be acceptable (Shakow & Huston 1936: 95). We feel that failure to consider this factor seriously can lead to grave errors in the interpretation of data. In any investigation it is axiomatic that the more other conditions can be controlled, the more accurate the information obtainable about the variables in question. In an unpublished study by the junior author on 61 schizophrenics the correlation between Stanford-Binet score and attitude rating was found to be .56. Other studies, published and unpublished, concerned with motor functions in schizophrenics gave correlation coefficients, between attitude and the particular function, of a similar magnitude. Wittman (1937) in a study of the relationship between cooperation and scores on memory and reasoning tests obtained coefficients of .68 and .15 for schizophrenics and paretics, respectively, on memory tests, and .62 and .14, respectively, on reasoning tests. The results on schizophrenics are quite consistent with those obtained by us. Her results on the paretics however are not confirmed by our findings.

TABLE 5

DIFFERENCE AND S.E.$_D$ BETWEEN MEANS OF REPRESENTATIVE AND NON-REPRESENTATIVE SUB-GROUPS IN VARIOUS DIAGNOSES

	Age	Education	St-B Score	Voc	DF	DB
General Paresis	−1.9 ±1.9	−0.4 ±1.1	−18.7 ±7.4**	−8.3 ±4.5	−0.24 ±0.28	−0.65 ±0.44
Feeblemindedness with Psychosis	−4.0 ±2.3	−0.2 ±0.6	−1.0 ±4.7	−0.6 ±2.6	+0.04 ±0.23	+0.57 ±0.37
Paranoid Dementia Praecox	+0.5 ±1.9	+0.3 ±0.8	−19.1 ±7.4**	−7.4 ±4.1	−0.30 ±0.27	−0.31 ±0.31
Hebephrenic Dementia Praecox	+0.1 ±2.2	−0.3 ±0.7	−24.3 ±8.8**	−10.8 ±5.7	−0.60 ±0.30*	−1.05 ±0.32**
Catatonic Dementia Praecox	−0.2 ±1.4	−0.3 ±0.7	−24.7 ±8.7**	−7.5 ±4.9	−0.59 ±0.25**	−0.27 ±0.40
Unclassified Dementia Praecox	−2.0 ±2.0	−0.1 ±0.7	−12.4 ±9.2	−6.8 ±5.2	−0.16 ±0.30	+0.37 ±0.43
Manic-Depressive	−2.7 ±4.0	+1.1 ±1.0	−21.8 ±11.2*	−2.0 ±5.8	−1.09 ±0.40**	−0.83 ±0.43
Psychopathic Pers. with Psychosis	+5.6 ±3.8	+1.1 ±0.9	−17.3 ±9.0	−3.0 ±5.0	−0.12 ±0.33	−0.20 ±0.38
Without Psychosis	+1.6 ±3.0	−1.5 ±0.7*	−19.0 ±8.3*	−12.0 ±4.8**	+0.11 ±0.30	−0.51 ±0.34

*Quotient D over S.E.$_D$ = 1.96–2.33
**Quotient D over S.E.$_D$ = 2.33 or more

their associated representative groups. In all significant item differences, also, the non-representative groups make the poorer showing. The graphs of the percents passing each item show very clearly the consistently poorer performance of the non-representative groups, although statistical significance is found only occasionally.

GENERAL PARESIS

Although these groups are very similar in age and education they differ significantly in mean Stanford-Binet score; the vocabulary mean of the non-representative group is lower but the difference is not significant.

Performance on the separate items of the scale, in terms of percent passing (on the basis of the number actually attempting each item; see footnote, page 375) is shown in the accompanying graph (FIGURE 1). Items showing significant, or possible significant differences all in favor of the representative group, are listed below:

$.05>P>.02$	$P\leq.02$
Comprehension (VIII-3)	Similarities (VIII-4)
Designs (X-3)	Date (IX-1)
Dissected Sentences (XII-4)	Definition of abstract words (XII-2)
Vocabulary (XIV-1)	
Problem questions (XIV-4)	

FEEBLEMINDEDNESS WITH PSYCHOSIS

The very slight differences between the means, the general overlapping of the distributions, and the performance on items, show a striking similarity in these two subgroups, both as to constitution and achievement. Only one item, repetition of syllables (X-8), shows a significant difference.

We may anticipate further results to state here that it is generally true that the representative surpass the non-representative groups, *i.e.*, that poorer cooperation means poorer performance. In view of this, we may look for some other explanation than that in the present group cooperation plays no role. Several possibilities appear. Either the non-representative group was originally superior to the representative and has, under stress of the psychosis dropped to the same level, or in this particular diagnostic group, either the factors which are used in determining representativeness of performance do not differentiate, or the examiner's judgment of representativeness is less valid. In view of the educational and occupational similarities as well as its theoretical unlikelihood, the first possibility may be dismissed. The decision as to representativeness is made on the basis of the subject's total behavior and attitude as well as upon the specific test performance. Further con-

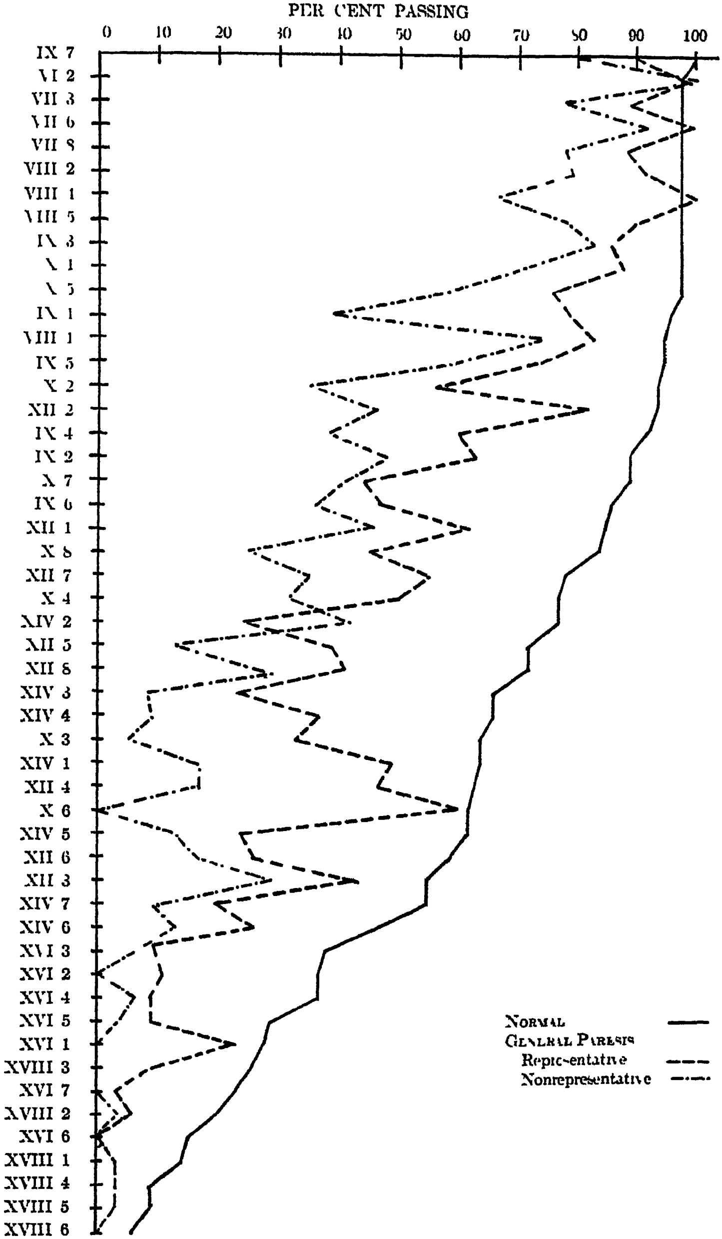

Figure 1. Percent passing each item: normal, representative, and non-representative general paresis. Items arranged in order of difficulty for normals. With few exceptions, the representative are markedly lower than the normal, and the non-representative are consistently lower than the normal.

sideration leads to the reasonable conclusion that an accurate estimate of representativeness is relatively more difficult to make here since not only the factor of psychosis must be considered but also that of mental deficiency. The whole picture is therefore much more complex. It thus seems probable that in this diagnostic group the degree of representativeness of any performance is difficult to judge and that this accounts for the close similarity between representative and non-representative performances*. The fact that the proportion of non-representative cases in this group is so small lends further credence to this interpretation.

PARANOID DEMENTIA PRAECOX

Except for the difference in Stanford-Binet means for which P is $<.02$ the mean differences here are in no instance significant. On all items (FIGURE 2), the percentages passing are, with one exception, higher in the representative group. There are a considerable number of items on which there is a difference by chi-square of some degree of significance. These are largely concerned with reasoning of both an associational and conceptual type, although a few primarily concern memory. They are as follows:

$.05>P>.02$	$P\leqq.02$
Absurdities (X-2)	Date (IX-1)
Comprehension (X-5)	Rhymes (IX-6)
5 D B (XII-6)	Designs (X-3)
Clock (XIV-6)	Reading & report (X-4)
Difference between abstract words (XVI-3)	Ball & Field (XII-3)
	Similarities (XII-8)

HEBEPHRENIC DEMENTIA PRAECOX

The non-representative are significantly lower on Stanford-Binet score, digits backwards, and possibly so on digits forwards. On only two items is the percent passing higher for the non-representative and then only slightly. The differences are usually markedly the other way. Significant differences are tabulated below. The types of items are of great variety and little can be said about predominance.

*There is theoretically, a further possibility, *viz.*, that at this low level attitude has little effect. We have, however, no evidence in support of this.

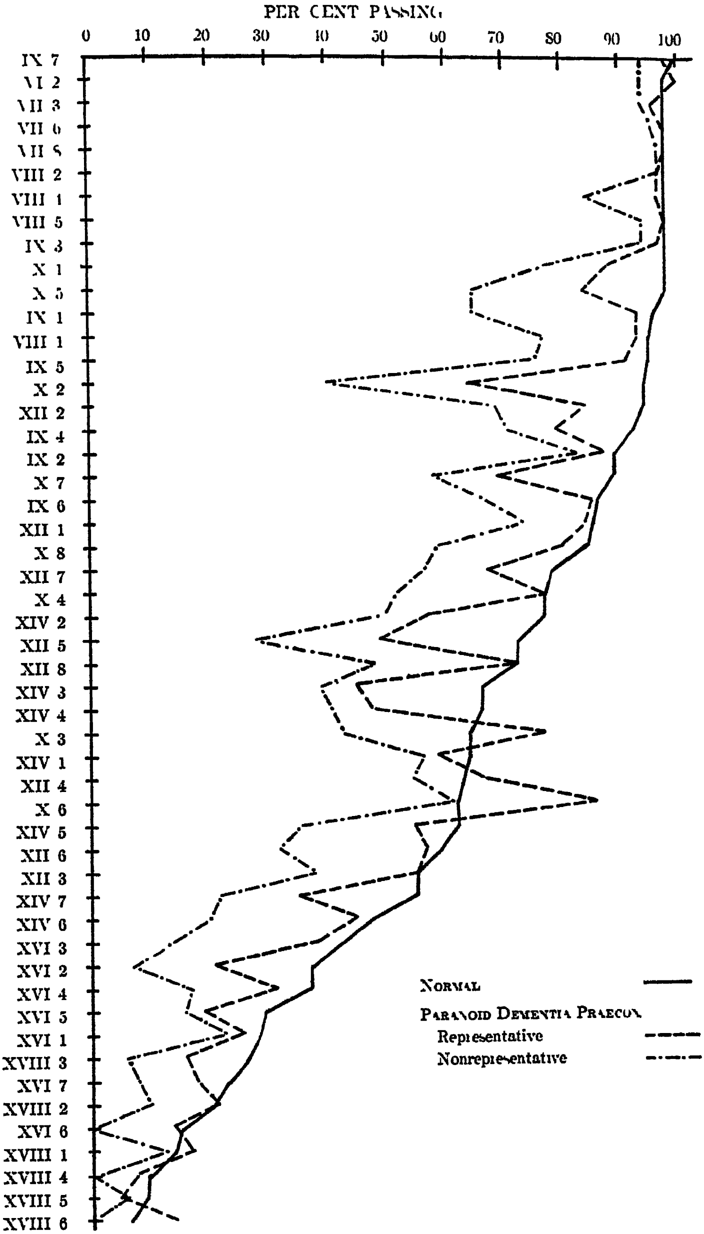

FIGURE 2. Percent passing each item: normal, representative, and non-representative paranoid dementia praecox. Items arranged in order of difficulty for normals. This representative group is generally somewhat lower than the normal, and the non-representative lower still, but the differences are not so marked as in FIGURE 1 (general paresis).

P values for items

$.05 > P > .02$	$P \leqq .02$
Comprehension (VI-1, VIII-3)	Definitions (VIII-5)
Picture description (VII-2)	4 DB (IX-1)
5 D F (VII-3)	Months (IX-7)
Differences (VII-5)	Absurdities (X-2)
Ball & field (VIII-1)	Reading & report (X-4)
20–0 (VIII-2)	Comprehension (X-5)
Similarities (VIII-4)	Vocabulary (XIV-1)
Making change (IX-3)	
Sentence construction (IX-5)	
Vocabulary (X-1)	
Abstract words (XII-2)	
Picture interpretation (XII-7)	
President & king (XIV-3)	

CATATONIC DEMENTIA PRAECOX

The representative are significantly higher on Stanford-Binet score and on digits forwards.

Except for three items (FIGURE 3) the non-representative are consistently lower. Significant differences are tabulated below. It is apparent that these are predominantly items involving thinking.

P values for items

$.05 > P > .02$	$P \leqq .02$
Sentence construction (IX-5)	Date (IX-1)
Rhymes (IX-6)	Weights (IX-2)
Absurdities (X-2)	
Fables (XII-5)	
President & king (XIV-3)	
Problems of fact (XIV-4)	

UNCLASSIFIED DEMENTIA PRAECOX

In this group there is, in general, less difference between the representative and non-representative groups than in the other dementia praecox groups. None of the differences between the means approaches significance.

There are few important differences in items. Only two are possibly significant: induction (XIV-2) and absurdities (X-2)—both conceptual thinking problems. It is probable that the relatively small number of differences found may be due to the rather colorless picture in the psychosis which offers few obvious indications of attitude.

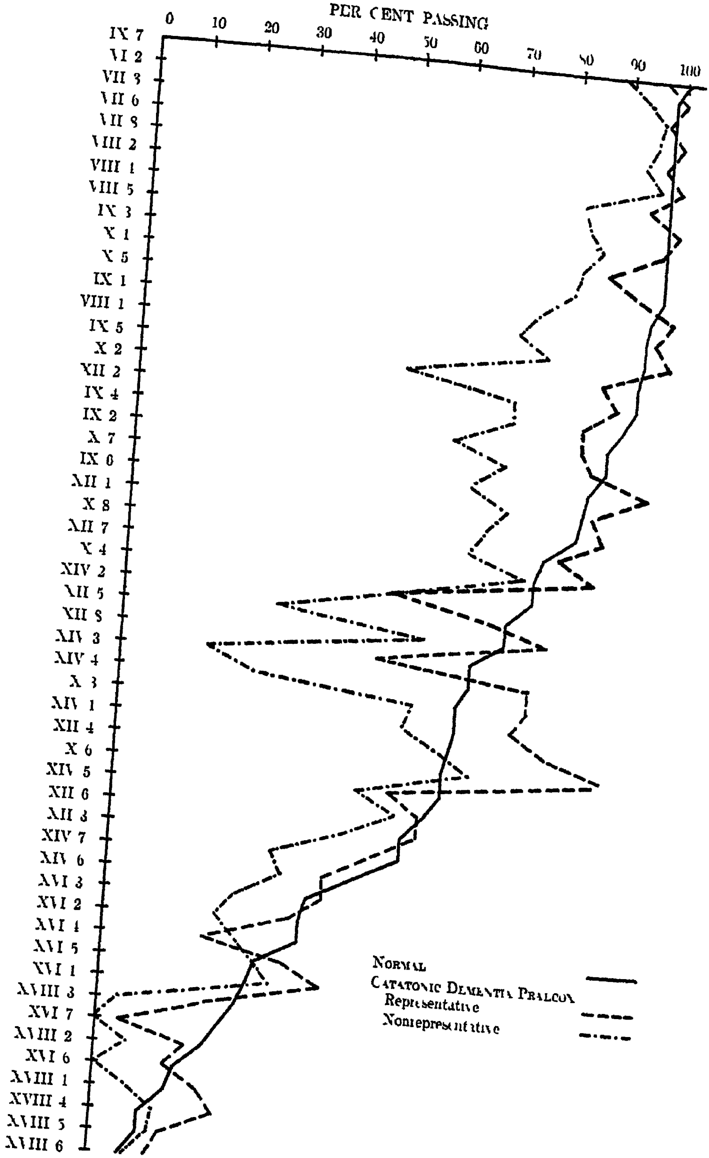

FIGURE 3. Percent passing each item: normal, representative, and non-representative catatonic dementia praecox. Items arranged in order of difficulty for normals. This representative group seldom varies markedly from the normal in either direction. The non-representative group is generally considerably lower.

MANIC-DEPRESSIVE

The differences in means are significant in only one instance—digits forwards. The Stanford-Binet score is 22 months lower for the non-representative, and of possible significance. Vocabulary means are practically identical. The non-representative group performance is generally markedly lower than that of the representative group. Problems of fact (XIV-4) and 8 digits forwards (XVIII-3) are significantly lower and absurdities (X-2) possibly so.

PSYCHOPATHIC PERSONALITY WITH PSYCHOSIS

The differences between means are slight except for Stanford-Binet score and even this is not significant. The trend however is constant; the non-representative are lower, except for nine items on which they equal or surpass the representative. In only one instance is the difference between the two groups in any degree significant: syllables (X-8), in favor of the representative group.

WITHOUT PSYCHOSIS

The two groups of this diagnosis show rather marked differences, significant for vocabulary, possibly so for Stanford-Binet score. The non-representative are generally lower on items, as shown in FIGURE 4. The marked differences are shown below and seem largely to fall in the vocabulary and reasoning type of test.

P values for items

$.05 > P > .02$	$P \leqq .02$
Rhymes (IX-6)	Ball & field (VIII-1)
Absurdities (X-2)	Vocabulary (VIII-6, X-1, XII-1)
Definition of abstract words (XII-2)	Free association (X-6)
	Problems of fact (XIV-4)

There is some question, however, as to whether or not the only factor differentiating these two groups is that of representativeness. The non-representative group is somewhat lower in educational level, and the difference in means is of possible significance. The difference between the vocabulary means is definitely significant. And, as has been pointed out earlier, the Taussig distributions are not very like; approximately one fourth of the representative group are unskilled laborers, but

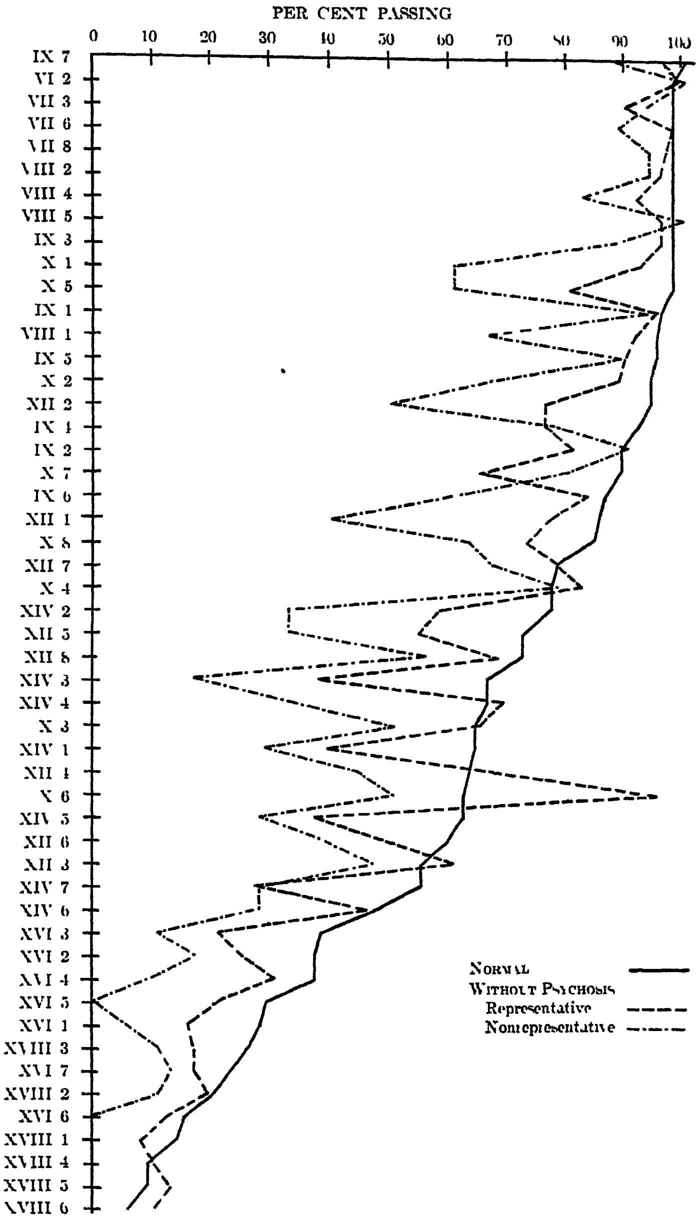

FIGURE 4. Percent passing each item: normal, representative, and non-representative without psychosis. Items are arranged in order of difficulty for normals. Although this group is not psychotic, it is definitely below the normal in test performance. The non-representative group is lower than the representative, but the differences are somewhat less marked.

almost one-half of the non-representative group were placed in this classification. It was possible to match 17 of the non-representative group with 17 of the representative group approximately for age and education. When this was done, the following means were obtained.

	Age	Ed.	St-B	Voc.	DF	DB
R	28.4	6.2	142	41.7	5.5	4.2
non-R	28.6	6.2	134	38.5	6.0	4.0

It would seem, so far as one can rely upon this sample, that some part of the differences reported above is probably due to differences in the original status of the two groups. But in the matched group, although vocabulary scores are now much closer, there is still some discrepancy in mean Stanford-Binet results. In the present instance, then, our two complete groups are not strictly comparable, and the effect of non-representativeness is not entirely clear.

SUMMARY AND CONCLUSIONS

From the previous discussion it is obvious that if we are to make any valid generalizations about the effect of attitude on Stanford-Binet test results the first step is to make sure that we are really dealing in all of the groups with the factors which enter into representativeness. With regard to three of the groups, feeblemindedness with psychosis, unclassified dementia praecox, and without psychosis, some question has been raised about the sources of variation. The evidence in the latter group shows that we are dealing in part with persons of lower original capacity in the non-representative group and that representativeness is apparently a secondary aspect of the problem. In the case of the feebleminded with psychosis there seems to be some cogency in the argument that the two types are hard to distinguish since it is particularly difficult to differentiate between unresponsiveness due to uncooperativeness and unresponsiveness due to stupidity. The unclassified dementia praecox group is believed to be one in which judgment is made more difficult by the rather colorless psychotic picture*, but this does not seem sufficient reason for dropping the group from the comparisons altogether. However, the other two groups do not seem to belong in this analysis, because of the doubts which arise regarding the sampling, and hence are eliminated in the summary of these comparisons. This will therefore include

*It is probable that this group includes a certain number of old hebephrenics in whom the distinctive hebephrenic coloring has been lost, and some who should perhaps be classified as feebleminded with psychosis.

the following groups: general paresis (GP), paranoid (DPP), hebephrenic (DPH), catatonic (DPC) and unclassified (DPU) dementia praecox, manic-depressive (MD), and psychopathic personality with psychosis (PP+).

From the tables presented thus far it is seen that there are a number of differences which are of a sufficient degree of significance to merit consideration. These are assembled in TABLE 6.

TABLE 6

SUMMARY OF SIGNIFICANT DIFFERENCES BETWEEN MEANS OF REPRESENTATIVE AND NON-REPRESENTATIVE SUB-GROUPS

	.05>P>.02	P≦.02
St-B		GP; DPP; DPH; DPC
Voc		
DF	DPH	DPC; MD
DB		DPH

It is apparent that vocabulary score is less affected by poor attitude than is total Stanford-Binet score. There is only one exception: in the unclassified dementia praecox comparisons (not in the above table because the P>.05) the ratios are approximately equal.

In TABLE 7 all items are listed, together with the groups showing significant and possible significant differences, and a tally which is merely the total number of groups showing a difference with a P less than .02 plus one-half the number showing a P between .05 and .02. In no instance is this difference in favor of a non-representative group. TABLE 8 lists these same items in the order of their discriminative value. It is interesting to note that two of the three items having the greatest tallies (X-2 and XIV-4) are items involving conceptual thinking. The third is giving the date (IX-1). Items tallying 1½ and 2 include two conceptual thinking, four associative thinking, two vocabulary, and two immediate memory.

In the order of the number of differences with P's less than .05 the groups run: hebephrenic, 21; paranoid praecox, 10; catatonic, 9; paretic, 8; manic-depressive, 3; unclassified, 2; psychopathic personality with psychosis, 1. The effect of attitude seems to be by far the greatest in the hebephrenic group with the catatonic and paranoid praecox groups following. It is least in the psychopathic personality, unclassified praecox and manic-depressive. The psychopathic personality with

TABLE 7

SIGNIFICANCE OF DIFFERENCES ON ITEMS BETWEEN REPRESENTATIVE AND NON-REPRESENTATIVE GROUPS

		.05 > P > .02	P = .02 or less	Tally
VI–4	Comprehension......	DPH		½
VII–2	Pictures...........	DPH		½
3	5 DF........... ...	DPH		½
5	Differences	DPH		½
VIII–1	Ball and field.......	DPH	DPC	1½
2	20–1...............	DPH		½
3	Comprehension.....	GP; DPH		1
4	Similarities..........	DPH	GP	1½
5	Definitions.........		DPH	1
IX–1	Date..............	DPC	GP; DPP	2½
2	Weights.....	DPC		½
3	Change	DPH		½
4	4 DB........... ...		DPH	1
5	Sent. constr........	DPH	DPC	1½
6	Rhymes....		DPP; DPC	2
7	Months.....		DPH	1
X–1	Vocabulary........	DPH		½
2	Absurdities	DPP; DPU; MD	DPH; DPC	3½
3	Designs	GP	DPP	1½
4	Reading...........		DPP; DPH	2
5	Comprehension. ...	DPP	DPH	1½
8	Sent. repet.........	PP+		½
XII–2	Abstract words.....	DPH	GP	1½
3	Ball and field		DPP	1
4	Dissected sent.......	GP		½
5	Fables............		DPC	1
6	5 DB...............	DPP		½
7	Pictures..........	DPH		½
XIV–1	Vocabulary.........	GP	DPH	1½
2	Induction...........	DPU		½
3	President & king	DPH	DPC	1½
4	Problem questions...	GP	DPC; MD	2½
6	Clock.............	DPP		½
XVI–3	Difference between abstract terms.....	DPP		½
XVIII–3	8 DF..............		MD	1

psychosis subgroup, with a tally only slightly lower than the unclassified praecox show much clearer differences and we are of the opinion that the small tally here results chiefly from the small non-representative group (n = 14) and does not reflect the actual situation clearly.

These results may be interpreted to mean either that in some diagnostic groups attitude affects cognition less than it does in others, or that in these the quality of representativeness is more difficult to judge. Both factors seem to be involved but in different degrees. The latter probably holds for the unclassified praecox (as well as for the feebleminded, omitted for this reason) because of the rather colorless picture. On the other hand, the hebephrenic group offers perhaps the best situation in which to judge representativeness and it seems fair to assume that the differences found are essentially due to attitude differences.

TABLE 8

SUMMARY OF DISCRIMINATIVE VALUE OF ITEMS IN REPRESENTATIVE NON-REPRESENTATIVE COMPARISONS

Tally	Item
3½	X-2
2½	IX-1; XIV-4
2	IX-6: X-4
1½	VIII-1; VIII-4; IX-5; X-3; X-5; XII-2; XIV-1; XIV-3
1	VIII-3; VIII-5; IX-4; IX-7; XII-3; XII-5; XVIII-3
½	VI-4; VII-2; VII-3; VII-5; VIII-2; IX-2; IX-3; X-1; X-8; XII-4; XII-6; XII-7; XIV-2; XIV-6; XVI-3

TABLE 9 gives for the various groups the number and percent of items falling into the different types of tests of the Stanford-Binet on which a P for the difference between representative and non-representative of $<.05$ was found.

It will be seen that all learned material—old and new—is least affected and conceptual thinking most, with associative thinking falling between. Although in some of the groups the disturbance may be slightly greater in other categories than in conceptual thinking, this is the category which is most commonly affected in some degree (in fact, in all but one instance). Further discussion of these findings may well be postponed

younger as are also the two groups of psychopathic personality, the psychoneurotic and the without psychosis groups. In all cases, however, the groups are, by any standards, adult, and distributions overlap to a great extent. We must remember, however, in considering the older groups, the possible effect of age in some of the individuals. It is impossible to estimate this exactly, especially since for the individual Stanford-Binet items age curves are not available. Within this range of ages we may at least discount any effect of age on vocabulary.

With the younger groups the situation is to some extent reversed; where there is any effect of age on test performance it is chiefly the normals who are penalized, so that we may be reasonably certain that any differences found are in spite of, not because of, age differences.

In only one instance does a group differ significantly from the normal in education—the catatonics are better educated. The total dementia praecox and the psychoneurotic groups are also better educated than the normal and these differences are of possible significance. All others have mean years of education closely approximating the normal.

For the most part, differences in Taussig distribution appear logically to reflect age differences rather than great differences in social background. The younger groups tend to have proportionately fewer professional workers and more semi-skilled and unskilled laborers, because many of these had insufficient time to learn a trade or a profession before hospitalization.

The comparisons are handled as in the preceding section. Correlation coefficients between various measures have been computed for most of the groups of 30 or more, for comparison with the normals. These are considered in a separate section, following the discussion of the means and individual items. Variation is also discussed in a later section.

The Diagnostic Groups

The data for each group will be found in the master tables in the appendix. Comparative data, however, are given in TABLE 10. In each case the difference shown is that obtained by subtracting the mean of the normal group from that of the abnormal group in question. The standard errors of the differences are also given. Significant differences are indicated by two asterisks, possibly significant differences by one. The means of the normal group are included for ready reference.

GENERAL PARESIS

As would be expected, this group averages slightly older than the normal, although only one subject is over 51 years of age. This factor is

TABLE 10

DIFFERENCE AND S.E.D BETWEEN MEANS OF REPRESENTATIVE GROUPS AND A NORMAL GROUP

	Age	Education	St-B Score	Voc	DF	DB
Normal.......... ..	36.1 ±1.5	8.1 ±0.3	163.6 ±3.1	54.5 ±1.9	6.69 ±0.1	4.87 ±0.1
General Paresis..	+4.5 ±2.0*	+0.5 ±0.5	−31.5 ±6.2**	−7.1 ±3.3*	−1.16 ±0.23**	−1.18 ±0.30**
Chronic Alc. Psy.... ...	+8.0 ±2.4**	−1.2 ±0.7	−17.7 ±6.2**	−4.6 ±3.6	−0.86 ±0.30**	−0.80 ±0.30**
Chr. Alc. without Psy...	+5.7 ±2.9	−0.9 ±1.3	−8.3 ±7.6	0.0 ±4.3	−0.44 ±0.33	−0.37 ±0.26
Acute Alc. Psychosis...	−0.2 ±2.5	+0.6 ±0.8	−9.4 ±8.5	+0.4 ±3.1	−0.69 ±0.34*	−0.40 ±0.44
Paranoid Praecox	−2.0 ±1.9	+0.4 ±0.5	−8.8 ±5.4	+1.6 ±2.9	−0.58 ±0.19**	−0.35 ±0.21
Hebephrenic Praecox....	−7.0 ±2.2**	+0.4 ±0.6	−34.2 ±6.2**	−12.5 ±4.9**	−1.16 ±0.18**	−0.56 ±0.25**
Catatonic Parecox......	−11.3 ±1.8**	+1.8 ±0.7**	+1.2 ±6.1	+2.5 ±3.7	−0.17 ±0.22	−0.10 ±0.30
Simple Praecox.........	−5.6 ±2.7	+0.9 ±0.9	−8.1 ±7.7	−1.4 ±3.8	−0.10 ±0.28	+0.37 ±0.30
Unclassified Praecox....	−8.0 ±2.2**	+0.3 ±0.7	−19.6 ±6.7**	−4.4 ±3.5	−0.74 ±0.23**	−0.76 ±0.30**
Total DP..............	−6.1 ±1.7**	+0.7 ±0.3*	−13.8 ±4.1**	−2.4 ±2.4	−0.6 ±0.2**	−0.4 ±0.14**
Manic Depressive.......	−1.1 ±3.4	+0.7 ±0.8	+2.8 ±8.1	+4.2 ±3.8	+0.05 ±0.29	+0.02 ±0.29
Psy. Pers. with Psy......	−12.2 ±2.3**	−0.5 ±0.7	−7.5 ±7.1	−5.6 ±4.5	−0.50 ±0.22**	−0.10 ±0.28
Psy. Pers. without Psy...	−11.0 ±3.4**	−0.3 ±0.7	−7.2 ±7.6	−5.3 ±4.5	−0.40 ±0.29	−0.16 ±0.30
Paranoid Condition.....	+3.7 ±2.6	+1.0 ±0.8	+1.1 ±6.3	+4.3 ±3.7	−0.74 ±0.25**	−0.01 ±0.31
Psychoneurosis.........	−8.3 ±2.3**	+1.3 ±0.7*	+5.5 ±5.7	−0.8 ±3.3	−0.15 ±0.20	+0.30 ±0.23
Without Psychosis......	−10.0 ±1.9**	−0.4 ±0.4	−10.9 ±5.1*	−6.5 ±2.6**	−0.68 ±0.18**	−0.36 ±0.23

*Quotient D over S.E.D = 1.96−2.33
**Quotient D over S.E.D = 2.33

not sufficient to account for differences although it may well increase them. The difference in education of the groups is negligible; the greatest difference in occupational status is in the skilled labor class which contains relatively few paretics. On all mean test results the paretics are much lower than the normals; the difference is possibly significant for vocabulary, and significant for the other three.

Item analysis (FIGURE 1, page 383) shows significant differences in the performances of the two groups on 22 items falling in the IX through XVI year levels and three others of possible significance as tabulated below:

P values for items by χ^2

Year	$P>.05$	$.05>P>.02$	$P=.02$ or less
IX	3, 7	1, 2	4, 5, 6
X	1, 6		2, 3, 4, 5, 7, 8
XII	2, 3, 4		1, 5, 6, 7, 8
XIV	1, 6		2, 3, 4, 5, 7
XVI	1, 5, 6	7	2, 3, 4

The items with a P of .02 or less are: vocabulary (XII-1); digits forward (X-7; XIV-7); digits backwards (IX-4; XII-6); sentence construction (IX-5); rhymes (IX-6); absurdities (X-2); designs (X-3); reading and report (X-4); comprehension (X-5); repetition of syllables (X-8); fables (XII-5 and XVI-2); pictures (XII-7); similarities (XII-8); induction (XIV-2); president and king (XIV-3); problem questions (XIV-4); arithmetic reasoning (XIV-5); difference between abstract words (XVI-3) and enclosed boxes (XVI-4). The others, of possible significance, are date and weights (IX-1 and 2) and repetition of syllables (XVI-7).

It is apparent that paretic performance is much lower than normal. In general, vocabulary and other remote memory items are least affected. It is very clear that immediate memory, in all spheres tested, is rather seriously and specifically impaired, which may contribute to the difficulty on other items. Conceptual thinking seems most impaired, with other types of thinking affected to a much lesser extent. (Note that the test situation in ball-and-field and dissected sentences is fairly concretely presented and apparently adequately comprehended.)

Foerster and Gregor (1909) using a variety of tests, including comprehension, reaction time, memory, etc., with 12 paralytics, in order to determine whether all functions were similarly affected, concluded that rote learning was more intensively affected than other functions in certain cases, whereas in others it was comparatively little affected.

Binet and Simon (1916) applying their test to a number of paretics,

concluded that this group showed a weakening of the whole intelligence which they interpreted as due to a disturbance in evocation. These authors noted, too, that the more automatised reactions were relatively less affected, and that speech, and word usage, *i.e.*, vocabulary, were generally above the intellectual level.

Wells and Kelley (1920) reported IQ distributions of 12 paretics with a median age of 48. From this distribution a mean IQ was computed by us and a mean MA of 128 was found; this is very close to the mean of 132 reported in the present study.

Schott (1930) in studying retests, listed MA's on first test for 16 paretics, aged 16-58. The mean MA is 152.5, considerably above ours.

Simmins (1933) found paretics lower than any other patients in both vocabulary and memory tests (not Stanford-Binet).

Landis and Retchetnik (1934) emphasize impairment in retention and immediate recall as the most frequent and severe mental change in paretics. They also found impairment with decreasing frequency in counting and calculation, reading and comprehension, memory of the recent past, and remote memory.

Hunt (1935) tested paretics and schizophrenics with a set of arithmetical progressions and a story containing absurdities. The subjects were not at first instructed to look for absurdities as in the Binet test. No comparisons with normals are given, except, "The narrative has been presented to a number of non-psychotic persons of varying degrees of psychological maturity . . . Most of these 'normal' persons noted more absurdities than the paretics did" (footnote, page 460). Our paretics also did poorly on the absurdities test (X-2).

Jastak (1937) found a mean MA of 135 for his 7 paretics and a mean vocabulary score of 53, MA equivalent 170*.

In the study of dementia praecox made by Kendig and Richmond (1940) Stanford-Binet MA's are given for a number of other groups for comparative purposes. Their results are reported only in terms of minimum, maximum, and median scores, no measures of dispersion are given, and distributions are only given for their major groups so that these constants cannot be calculated for their other groups. A further difficulty is that colored patients are included in unstated numbers in the separate groups. We can state only that their 69 paretics had a median Stanford-Binet MA of 11 years, that is, of 132 months, which corresponds almost exactly to our mean.

In general, then, except for the much higher mean reported by Schott, investigators are in accord in the matter of mean test level in paretics.

*Jastak (1934) uses his own MA equivalent based on a group of children.

CHRONIC ALCOHOLISM WITH PSYCHOSIS

The alcoholic group are all male. The groups differ significantly with regard to age, and the educational difference noted is probably in part a function of this age difference*. There are relatively fewer chronic alcoholics in Taussig Groups II and IV (in which most of the women are placed) but the difference is not significant.

This psychotic group is lower than the normal on all mean test results and the differences are significant except for vocabulary. To some extent these findings are undoubtedly influenced by the effect of age, but there is only one case over 60 years, although there are ten between 50 and 60. Age in this range has little influence on vocabulary but does to some extent affect Stanford-Binet score, although it is not known whether the effect is on specific items or in the way of a general lowering. Note that of the items given below as showing differences, only two of the possibly significant ones have a time limit.

P values for items by χ^2

$.05 > P > .02$	$P \leqq .02$
Sentence construction (IX-5)	Absurdities (X-2)
6 digits forwards (X-7)	7 Digits forwards (XIV-7)
Vocabulary (XII-1)	
Abstract words (XII-2)	
Fables (XII-5)	
5 Digits backwards (XII-6)	
President and king (XIV-3)	
Clock (XIV-6)	

Not much comment can be made about these, except to point out that they are distributed rather evenly among vocabulary, immediate memory, sustained associative and conceptual thinking. In many of these, elements are presented successively and preceding ones must be retained and combined with later ones. A tentative summation might thus superpose upon the already demonstrated loss in rote memory, a further loss in the ability to maintain a definite set so as adequately to organize sequentially presented material.

Pressey (1917) reports point scale examinations of dementia praecox and chronic alcoholic patients (presumably with psychosis). His 25 alcoholics averaged 30 years of chronological age, the range being 15 to 55, and 126 months in mental age. The group is not only much younger than ours, although he states the condition to be "the result of years of dissipation", but 20 months lower in mental age (assuming Stanford-Binet MA and point scale MA to be equivalent). He compared his

*Cf. discussion in Shakow & Goldman (1938).

results with the normal standardization material for the same MA, and found differences greater than 15% in number passing for five tests—normals being better on free association and drawing designs from memory, alcoholics being better on comprehension, absurdities, and definitions of abstract words. Superficially his results appear to contradict those of the present report. It must be remembered, however, that he was comparing his adult psychotics to children; the two tests at which his chronic alcoholics were poorer are relatively easier for children than for adults; the reverse is true of the other three, at which his adults were better (Weisenburg, Roe, & McBride 1936: 60).

CHRONIC ALCOHOLISM WITHOUT PSYCHOSIS

There are no significant differences with respect to age, education, or occupation, although the group includes a higher percentage of semi-skilled laborers and a lower one of semi-professional and business categories. It is a very small group, so no correlations were run.

The mean test results do not in any instance differ much from the normal, and, except for one item, induction (XIV-2), all items have P values of more than .05. This item did not show a significant difference between the normals and the psychotic alcoholics.

ACUTE ALCOHOLIC PSYCHOSIS

The group is very like the normal in age, education, and occupation. The mean vocabulary score is practically identical in this and the normal group; Stanford-Binet score and digits backwards are lower but not markedly so; the mean for digits forwards is lower, with P just less than .05. None of the items has a P of less than .05. Most of these patients, when they reach the psychologist, have attained the greater part of their recovery from the attack of alcoholic hallucinosis which resulted in their hospitalization. Even so, they show some early changes in the direction of the chronic alcoholic with psychosis—lowered achievement in rote memory and in the detection of absurdities.

Jastak (1937) reports a mean Stanford-Binet score of 150 and a mean vocabulary MA of 159, equivalent to a score of 48 by his norms, for 15 patients diagnosed as alcoholic psychosis, type not specified. It can be seen that his Stanford-Binet mean falls midway between ours for chronic and acute alcoholic psychosis, whereas his vocabulary score is somewhat below that of our chronic alcoholics.

The Kendig-Richmond (1940) median MA for 24 "alcoholic psychoses" was 129.

Comparing the effect on the three groups in relation to the normal, it

is seen that alcoholism *per se* seems to have relatively little effect and that it is only when psychosis is superposed that performance is really disturbed.

PARANOID DEMENTIA PRAECOX

In age and education this group is markedly like the normals; occupational distributions are similar, though with relatively more of class V in the hospital group. The psychotic group is very slightly higher on mean vocabulary score; other mean test results are lower, and on digits forwards the difference is significant.

The item analyses show 6 significant and 5 possibly significant differences (FIGURE 2, page 385). The former comprise detection of absurdities, comprehension, and digits forwards at X; fables at XII (not at XVI) and president and king at XIV; on these the normal were superior; on memory for designs (X-3) the paranoids surpassed the normal. The possibly significant differences, all in favor of the normal, are: 4 digits backwards at IX, vocabulary at X, and induction, problems of fact, and 7 digits forwards at XIV. With the exception of the immediate memory and vocabulary items, these tests fall into the classification "conceptual thinking"—the type of test which seems primarily affected.

Rawlings (1921) reported material for 16 "apparently well preserved cases of paranoid dementia praecox", on the Yerkes Point Scale. They average 10.9 (130.8 months) in MA, considerably lower than the Stanford-Binet mean score reported here. Apparently all tests were representative. No information as to age, education or occupational status of the group was presented.

Barnes (1924) reported that, in general, dementia praecox paranoids were lower than normals (Stanford standardization group) except on XIV-2, which for our group shows a possibly significant difference. She noted that between 60 and 75 percent is the expected frequency of passes for normals, and since 70 percent of her paranoid group passed this item she concluded that it is as easy for them as for normals. Her paranoid group varies in number for different items from 3 to 33. If items are arranged according to difficulty, the rank correlation between her group and ours is +.93. A direct item-to-item comparison shows a number of significant differences, but as her group appears to have a mean score much lower than ours, the amount not determinable precisely from her records, this is inevitable. She gives no data as to the age and educational levels of her group.

Babcock (1933) gives no material which can be used for specific comparison but says of the paranoids that they have a practically normal

distribution as to intelligence—determined presumably on the basis of vocabulary—although they are defective in learning ability.

Trapp and James (1937) commenting that "as a rule the IQ of the paranoid patient is higher than of any other group" present IQ's for 19 patients on representative examinations. From these an average MA at first test of 171 can be computed; it is notably higher than that reported here. The average CA of their subjects was 32 years. Their group was considerably smaller than ours but it is not apparent why their mean Binet score should be higher; their mean Binet score for hebephrenics is also considerably higher than ours. They do not give descriptive data for their group, by which differences in sampling could be determined.

The 41* cases reported by Kendig and Richmond (1940) had a median CA of 33.8. Their system for recording education differs somewhat from ours, but so far as we can tell from their data, mean years of education for their group was 8.5. No occupational data are given, nor is it known how many colored patients are included in this group. However, in education and age they do not differ from ours. Their Stanford-Binet median is 148, and vocabulary median age is 12, equivalent to a score of about 41. Our means for these are 155 and 56. It is possible to make some comparison by items as they give percentages failing each item. Rank correlation of their group with ours, on this basis, gives a coefficient of +.93.

HEBEPHRENIC DEMENTIA PRAECOX

Although this is definitely an adult group it is significantly younger than the normal. It has, however, the same educational level and a similar Taussig distribution. All mean test results are significantly lower.

This group has the greatest number of significant—25 and possibly significant—8, differences on individual items; they appear as early as the VIII year level, and in every year level after that. Vocabulary at VIII, X, and XII (but not at XIV, XVI, and XVIII), definitions at XII (possibly at VIII) and differentiating between abstract words (XVI-3) are significantly lower. Of the memory tests, digits forwards (XVIII-3 possibly), syllables at X and possibly XVI, and designs (X-3) are all significantly lower. Comprehension tests are lower (VIII-3, X-5, XIV-4). Tests involving interpretation as well as comprehension are lower (XII-5, XVI-2, XII-8), as are items requiring comparisons (VIII-4

*Although Kendig and Richmond reported on a total group of 500 cases of dementia praecox, only 160 of these were classified as to type.

possibly, XII-8, XVI-3) and others requiring constructive activities (XIV-2, XVIII-2). Visual imagery is lower (XVI-4 and XIV-6 possibly) as are also date (IX-1) and arithmetic reasoning (XIV-5). Ball-and-field is significantly lower at VIII, not at XII. Digits backwards are significantly lower at IX and XII, but not at XVI and XVIII. Although the differences in vocabulary are not significant after the XII year level, this test is much more affected in the hebephrenics than in any other group, and P for the difference in mean scores is less than .02. The hebephrenics show a marked and generalized decrement in all functions except those involving remote memory other than vocabulary.

Barnes' (1924) study contains a hebephrenic group large enough for some comparison with ours. Her groups run irregularly in number from 3 to 21 for separate items. Item difficulty gives a rank correlation of +.92 with our group. Examination of the individual items shows only one difference between the performances of the two groups which is significant: detection of absurdities (X-2) passed by 3 of 17 in her group and by 16 of 31 in this group. (It was passed by 61 of the 65 normals).

Babcock (1933) found hebephrenics to be generally below average in intelligence (based on vocabulary) attributing this to a course of impairment beginning before the age of 14. She considered inability to interpret and to learn the most characteristic deficiencies in this group.

The group studied by Trapp and James (1937) had a mean MA of 148 (calculated from their IQ's) for 11 hebephrenics averaging 27 years of age, a mean higher than ours.

The 32 hebephrenics reported by Kendig and Richmond (1940) had a median CA of 31.2, and averaged (as closely as we could compute it) 7.1 years of education. Their Stanford-Binet median was 138, and vocabulary median 30. Their group was thus slightly older, less educated (number of colored included is not known), 9 months higher in Stanford score and 12 points lower in vocabulary. The lower vocabulary score may well be associated with the lower educational level; the difference in Stanford-Binet scores is probably not significant. Rank correlation for the items is .95.

CATATONIC DEMENTIA PRAECOX

This group is the least like the normals in the descriptive characteristics: they average 11 years younger, have had almost 2 more years of schooling, and there is a marked preponderance of unskilled over skilled workers (probably resulting from the age difference) although this is not sufficient to cause a significant difference between the distributions. Test results are extremely close in every instance, there being no P less

than .05 for differences between means. No significant differences were found in item analysis; possibly significant differences appeared for free association (X-6) which was easier for the catatonics, and for induction (XIV-2) which was harder for the catatonics (FIGURE 3, page 387).

Babcock (1933) found that the distribution of mental level in catatonics was practically normal, but that all were behind in school achievement (not borne out by our results). She considered them to show greater weakness in the motor phase of the response relative to learning.

The four catatonics reported by Trapp and James (1937) averaged 28.5 years in age and 145 in MA. Their catatonics are thus lower, their hebephrenics and paranoids higher than ours; their n's are 4, 11, and 19 respectively.

The Kendig-Richmond (1940) group of catatonics numbered 51, had a median chronological age of 22.0 and an average of 8.8 years of education (our estimate from their figures). Their median Stanford-Binet was 144, and median vocabulary score 41. Item rank correlation is +.91. It is apparent that our group is older, better educated, and considerably higher in test results. As we have already indicated, ours is a relatively selected group.

SIMPLE DEMENTIA PRAECOX

This group is similar to the normal in age and education, and while the Taussig ratings show a disproportionately larger number of unskilled laborers, the difference is not significant. All of the mean test results are very close.

Two items are of significantly greater difficulty for this group: detection of absurdities (X-2) and comprehension (X-5); one, memory for designs (X-3), is possibly significant.

The simple dementia praecox patients reported by Trapp and James (1937) have an average CA of 28.7 and an average MA of 153, very close to that of our group.

On the other hand, the 14 reported by Kendig and Richmond (1940) had much lower medians on Stanford-Binet—127, and vocabulary—23. Their group was younger and considerably less well educated. Neither group is very large so that differences in the samples, such as the inclusion of a few colored patients or of non-representative test results could easily effect such differences in averages. Item rank correlation was +.88.

UNCLASSIFIED DEMENTIA PRAECOX

This group is significantly younger than the normal but the educational level is practically the same. Occupational distributions do not

differ significantly although the group of unskilled laborers is relatively larger. Some of these are younger members of the group who have not had time to learn a trade but who normally would do so. Four of those not rated were still in school when committed. The Stanford-Binet mean is 20 months lower, with a P of less than .02, but vocabulary is only slightly lower than for the normals. Digits, both forwards and backwards, show significant differences.

Item analysis shows 14 significant and 6 possibly significant differences. The first group includes 2 comprehension items (VIII-3 and X-5); 2 digits forwards (X-7 and XIV-7), both fables (XII-5 and XVI-2), tying a bowknot (VII-4), one digits backwards item (IX-4), sentence construction (IX-5), one vocabulary item (X-1), detection of absurdities (X-2), sentence memory (X-8), defining abstract words (XII-2), president and king (XIV-3). Possibly significant differences were found for: ball-and-field (VIII-1, but not at XII-3), giving the date (IX-1), reading and report (X-4), problem questions (XIV-4), arithmetic reasoning (XIV-5), and enclosed boxes (XVI-4). The types of test most affected are those involving conceptual and sustained associative thinking. There is also some effect—approximately equal in amount—on all the other types, including vocabulary.

TOTAL DEMENTIA PRAECOX

The material thus far presented, comparing various types of dementia praecox with a normal group, shows distinct differences among the types. This will be brought out even more clearly subsequently when the various types are directly compared. Since, however, previous studies deal with the diagnostic group dementia praecox as a whole, the types have here been combined. It must be understood that we do not consider this procedure intrinsically defensible. We so treat our material only in order to make possible a comparison of it with the findings reported by other workers.

The data on the mean for this group show it to be younger and somewhat better educated than the normal group*. All test results are lower,

*Schizophrenics, then, do *not* in general fall below the average educational level, as has been argued by several authors. Additional corroboration of this point can be found in the report of Massachusetts hospitals for 1935. During this year 723 schizophrenics were admitted to all state hospitals; the average age was 38.1 and the educational distribution as follows: 66% grammar school; 29% high school, 6% college. Of the normal group from 30-39 in the Shakow-Goldman vocabulary study (1938), the educational distribution was: 65% grammar school; 25% high school; 10% college.

Kendig and Richmond (1940) believe that their group of dementia praecoxes is definitely markedly retarded in schooling. Their figures are 75% completed grade school, 20% had some high school training and 5% had some college work. Their figures are somewhat lower than ours, but without measures of dispersion it is impossible to tell whether this difference is of significance, although it may well be. They have, however, *in estimating the extent of retardation in the group apparently overlooked* the important factor of age in computing expected normal years of education. The mean years of education for their total white group is approximately 8.5, very close to that for our group. However, mean years of education for their colored group, which constitutes about one-seventh of their total group, is approximately 6.0. This distorts the figures considerably.

and for the Stanford-Binet score, digits forwards and digits backwards the difference is statistically significant. Vocabulary scores differ by only 2.4 points.

On these items the performance of the normal group is significantly higher: digits backwards at IX; vocabulary at X; digits forwards at X and XIV; absurdities (X-2); comprehension (VIII-3 and X-5); differences between abstract words (XII-2); induction, (XIV-2); president and king (XIV-3) and fables at XVI. Only on free association (X-6) is the dementia praecox group superior. On these tests, the normal group is possibly significantly higher: tying a bowknot (VII-4), date (IX-1), repetition of syllables (X-8 and XVI-7), problem questions (XIV-4), arithmetic reasoning (XIV-4), and enclosed boxes (XVI-6). That is to say, the dementia praecox cases are affected most on tests involving conceptual reasoning and somewhat less on the other types of tests.

Pressey (1917) examined dementia praecox patients with the Yerkes Point Scale. The make-up of his group with regard to type is not clear. They were selected as those having an MA between 8 and 12 years on the point scale and having given evidence in the history of previous development above this level. The average MA of the group was 126. His primary purpose was to compare this group with a group of feebleminded, but he adduced comments on the performance of the dementia praecox patients in relation to normals—presumably based on the data on which the scale was standardized. This comparison showed that his praecox group scored 77% of normal on comparisons (similarities), 71% of normal on free association, 67% of normal on sentence construction, 54% of normal on drawing designs from memory, and 138% of normal on the definition of abstract words.

In the paper by Wells and Kelley (1920)*, computations from the IQ distributions for their 22 dementia praecox patients resulted in a mean of 166.7, 17 months higher than that of the group reported here. They discuss test failures above and below the MA level. For all their groups they found that frequency of passing above the MA was most marked in the vocabulary and digits forwards tests. They conclude, with regard to dementia praecox cases, "The disorder attacks first the more fundamental, instinctive, 'real' types of conduct, and leaves relatively untouched the more conventional 'laboratory' type of reactions. Particularly does this apply to the language mechanism, through which any degree of intellect is to be manifested. Hence the high IQ in grave dementia praecox cases."

*The work of Wells and Kelley was done at McLean, a private hospital, with a patient population distinctly above the average. This must be taken into consideration in comparing their results with ours.

Wentworth (1923) divided her 200 cases, selected only for willingness to cooperate, into three groups according to deterioration, thus: (*a*) deterioration to a general low level; (*b*) definite blocking of thought processes; (*c*) no blocking of thought processes. For the first group she reported the type of questions most often failed to be any requiring real thinking, judgment, or reasoning; that attention was not long sustained and that sentence memory was poor; memory for digits was better—the higher types of this class repeated digits well above the MA level. This group was probably largely hebephrenic. In the second group, she also found memory for digits peculiarly intact, and the questions most often failed above the MA level were: weights, absurdities, designs, comprehension, abstract words, fables, picture interpretation, and similarities. The third group showed no clear differences. In general, her results are very like ours, with one striking exception: she reports dementia praecoxes to be relatively higher on digits forwards than on general MA level, as do also Wells and Kelley. Unfortunately, she does not give numerical results. A mean MA of 125 can be computed from her data, considerably below our mean for the whole group, but quite similar to that for our hebephrenic group.

It is to be noted that in our study the mean of the dementia praecox group for repeating digits forwards is only slightly above the 10 year norm, hence below their MA mean. A scatter diagram shows that 50 cases, or only 28% of our group, tested above their MA level on digit repetition (locating digits at the test level, *i.e.*, 6 at X, 7 at XIV, and 8 at XVIII). Of these, 2 could repeat 5, 6 could repeat 6, 14 could repeat 7, and 28 could repeat 8 digits. All of the last group, naturally, were above their MA level. The 50 were distributed by types thus: 30% paranoid; 22% unclassified; 22% simple; 18% catatonic, and 8% hebephrenic.

Cornell and Lowden (1923) report a median Stanford-Binet MA of 124 for 50 dementia praecox cases. Types are not noted.

Schwartz (1932) applied Babcock's scale to 110 dementia praecox patients, presumably of all types. He computed the sum of MA's of all subjects on one test and expressed it as the percent of the sum of MA's for vocabulary. The percent for repetition of digits was 69, for counting backwards 65.6 and for paragraph memory 54.3.

Hunt (1935) noted that schizophrenics were very poor in detecting absurdities.

Michaels and Schilling (1936) found a mean Binet score of 180 for 36 schizophrenic patients, on consecutive admissions. This includes only

patients accessible on admission and is probably, relative to ours, a selected group.

Harbinson (1936) in a study of 36 psychotics at the Bethlehem Royal Hospital, of whom 11 were schizophrenic, used Spearman's 'g' tests, Terman vocabulary, digits forwards and backwards. Results for the latter were not presented. She found only three of the schizophrenic patients, or 27% of her cases, to show intellectual deterioration by the criterion of a score on 'g' lower than that on vocabulary. Her digits forwards mean for these 11 is 8.8, many of her cases reaching the maximum of 10. No description of types or selection was given.

Wittman (1937) in an attempt to evaluate the theories of the basis of dementia praecox, gave a number of tests to paretic, praecox and normal subjects. Since, for the dementia praecox group, correlations between ability tests and tests of cooperation were high, and for the paretics they were low, she concluded that the "dementia" in dementia praecox was functional. In all of her ability and memory tests, mean scores for the paretics were lower than for the praecoxes*. In our groups, the means for the combined dementia praecox groups are everywhere higher than the paretic means, and on item analysis the paretic tally of significant differences from the normal is 29 and the total dementia praecox tally is 13 (the hebephrenic group alone tallies 32) so that our results confirm hers.

Jastak's study (1937) included 16 dementia praecox cases, types unspecified. These had a mean Stanford-Binet score of 132, and a mean vocabulary MA of 151, equivalent to a score of 45. Both are lower than the means of our total group.

The median given by Kendig and Richmond (1940) for their 429 whites is 143. This group is discussed fully below.

A survey of the results obtained by others indicates that they fall into two groups: one which obtains a fairly low mean score for the dementia praecox and another which obtains a quite high score for them. In the former belong Pressey (1917), Wentworth (1923), Cornell and Lowden (1923), Jastak (1937) with means of 126, 125, 124, and 132 respectively. In the latter belong Wells and Kelley (1920) with a mean of 166, and Michaels and Schilling (1936) with a mean of 180. Since the latter results were obtained from selected populations we do not believe that they are comparable with those of the first groups. The Kendig-Richmond mean is close to our mean for the representative group of 149.8, a

*Since she presents no standard errors or any measures of dispersion, their significance is not certain, but the consistency of the trend lends support to her position.

value which would lead us to believe that the means obtained by both of the above groups of investigators are extreme.

On the chance that our group was *too* well selected we have computed the mean for our total group of 300 dementia praecox--representative (181) and non-representative (119)—obtaining a mean of 140.6, still higher than that generally reported. An examination of the mean and distribution of our non-representative group (the mean is 126.7) leads us to suspect that the group of investigators first mentioned may have either dealt largely with non-representative cases or with a great preponderance of hebephrenics (whose mean for our representative group is 129.4) or with both. We have no other way of reconciling our results with those ranging about a mean of 125.

The extensive material of Kendig and Richmond offers some interesting comparisons with our data, although only a limited number of these can be made. Their main group of dementia praecox cases included 41 paranoid, 32 hebephrenic, 51 catatonic, and 14 simple. (The remaining patients were not classified as to type.) There were 66 colored in this group, whose type classifications are not given. Some figures are given for the whites only, however, and the rest of this discussion will be based on these 429 cases (their figures). Their medians are: CA, 26.8; education, 8.4; Stanford-Binet MA, 143; vocabulary score, 41. Our mean test results are somewhat higher; the difference in these large groups may be significant, but this cannot be determined since means and standard errors are not given. If both groups have a negative skew, which is usually the case in adult test results, medians will be somewhat lower than means, and the difference might be accounted for on this basis. It is also probable that they included a few cases which we would have called non-representative. In general, it seems that we are in fairly close accord in results in terms of central tendency.

It is also of interest to compare results on the separate items. The rank correlation is +.95. In only a few instances are differences in percent passing larger than 15. Kendig and Richmond compared their psychotic and normal groups on item performance by inspecting the percents failing each item, and considered a difference of five percent at any level of failure to be significant. It is not possible to make any very exact comparison of their analysis and ours because of the considerable differences in technique, but we quote their general conclusions (p. 70) which are in close accord with ours,

"Since our findings are so similar with whatever group we compare the praecox, it is warrantable to combine and summarize them. The following list, then, represents

the tests which in general are more difficult for the praecox than for the "normal", the paranoid, and, from the 10-year level down, the defective:

*Mainly Eductive**

Fables: XII-5 and XVI-2
Abstract words: XII-2 and XVI-3
Vocabulary: XIV-1
Induction: XIV-2
Problems of fact: XIV-4
Ball and field: VIII-1 and XII-3
Dissected sentences: XII-4
Pictures: VII-2 and XII-7
Absurdities: X-2
Comprehension: X-5
Differences: VII-5
Similarities: XII-8

Mainly Non-eductive

Digits forward: VII-3, X-A, and XIV-A
Digits reversed: IX-4
Designs: X-3
Reading and report: X-4
60 words: X-6
Date: IX-1
Weights: IX-2
Syllables: VI-6

Malamud and Palmer (1938) have used the 1916 Stanford-Binet, short form, for an extensive comparison of three groups of 100 subjects each: schizophrenics (39 hebephrenic, 17 simple, 12 catatonic, 15 paranoid, and 17 unclassified), organic psychosis (44 central nervous system lues, 17 alcoholics, 31 senile, and 8 miscellaneous), and subnormals, but since they limited their subjects to those with MA's between 8 and 12 years (the mean for each of these groups was 126) who were cooperative and had no handicaps other than those specified, their material is hardly comparable. After a careful analysis of their material, they conclude that "deterioration" is manifested chiefly in activities requiring the directional control of thought. This is not far from our own findings. Although the point of view differs they would appear to mean such activities as we have named conceptual and associative thinking. However, in addition to disturbance in these functions, we found considerable disturbance in immediate memory and in some other types of performance which do not appear in their analysis.

*This includes all items classed by us as conceptual and associative thinking, except XVI-4, XVI-6, and XIV-6, and also all vocabulary and definition items.

MANIC-DEPRESSIVE

This group comprises manic, depressed, and intermediate types; it is too small to subdivide. Piotrowski (1937) without adducing data, remarks on the large difference between the different types of manic-depressives, and the argument against lumping them into one group applies here as well as to dementia praecox types especially since individual patients change in different stages. We do so combine them with the comment that the group is mixed, although in this particular instance, it is not as heterogenous as it might at first appear to be. Psychometrics are rarely attempted in the acute stages, and when they are, are almost never representative. Most of these patients were examined during comparatively quiescent periods, *i.e.*, near the normal. It is apparent that the group very closely resembles the normal in age, education and occupation. This is also true of all test results. Furthermore, on item analysis, no significant or possibly significant differences were found.

Curtis (1918) excluded manic-depressives from her study of psychotics on the ground that they were so near the normal. Wells and Kelley (1920) reported on 43 manic-depressives of various types. The median age was 47, and the mean Stanford-Binet score 171 (computed from their IQ frequency distributions); although their group is older than ours, the Binet means are quite close (ours was 166).

Barnes' (1924) manic-depressive group would probably have an average score considerably lower than the one reported here, although it cannot be determined accurately from her data. The rank correlation for her items with ours is +.90.

Dearborn (1931) stated, "the more purely manic-depressive a psychosis is, the less deterioration it causes in the mind".

Michaels and Schilling (1936), found for 23 manic-depressives a Binet score of 169 months (14.1 years), higher than ours by less than three months.

Jastak's (1937) 23 manic-depressives had a much lower mean Stanford-Binet than ours—149—with a vocabulary score of 52, MA equivalent 168.

The group of Kendig and Richmond (1940), 65 cases, had a median MA of 148, very close to Jastak's.

It is apparent that there is some disagreement, Barnes, Jastak and Kendig, and Richmond report similar low averages, while Curtis, Wells and Kelley, Michaels and Schilling and Dearborn roughly agree with ours. It is not apparent why any of these groups should be lower than the others. This was also the case with Barnes' paranoid group. Possible selective factors in this instance cannot be determined directly

from her material or by inference from her specific interest, which is a little obscure (*vide* her remarkable peroration), nor do the others give sampling data.

In contrast to the above findings, there are several recent studies from England on the relationship between manic-depressive insanity and feeblemindedness. Duncan, Penrose and Turnbull (1936) reported a survey of all the patients in Severalls Mental Hospital, and Duncan (1936) later reported a more detailed analysis of these results for the manic-depressives. Patients were classified as certifiably feebleminded (apparently imbecile or lower), dull but not certifiable, and normal in this way, "Mental capacity was rated partly on the patient's ability to answer *a few standardized questions*, taken from Binet's Mental and Scholastic Tests, of which the reading tests were found to be the most useful. The patient's past history and also the school record were taken into consideration . . . " (p. 238). They found a 17.3% incidence of mental defect and a 23% incidence of dullness and noted that the manic-depressives and epileptics had the "strongest association" with lower mentality. In the schizophrenics they found a 38% incidence of mental defect. In the new admissions, the figures were 24% for schizophrenics and 27% for manic-depressives.

Duncan analyzed the material for 287 manic-depressive patients, and found, by these standards, 24% to be feebleminded and 22% dull, or 46% subnormal, but he felt that figures on new cases are perhaps more accurate and gave for 81 of them a 6% incidence of feeblemindedness and a 21% incidence of dullness, and states "these figures . . . imply an etiological factor more common than any other which has been suggested for this form of psychosis". It seems necessary to point out only that in a sample selected at random from the general population a 6% incidence of feeblemindedness—by similar standards— is not far above expectation and cannot possibly in itself be taken to indicate any association with manic-depressive psychosis*. Apart from this, we know nothing about the representativeness of the examination beyond a remark, in answer to a critic, that it was surprising how well many of the patients cooperated, although the use of school history in making the final rating probably to some extent effects unrepresentative results. Nor is their use of "a few standard questions" legitimately comparable to a standard psychometric examination. This is hardly the place for a criticism of his discussion of the clinical similarities between manic-depressive and feebleminded

*Wechsler (1929) puts the incidence of feeblemindedness at 3%, basis unspecified, but very probably the army report which gave 2.98% of the white draft as having an MA under 10 years. On the theory that the draft was somewhat low, the figures are discussed and rather casually revised by Davies (1923) who gives 5.3% as his estimate. Burt (1937) gives the incidence in the British Isles as varying from 1½% to 3% in different districts, by somewhat more exact criteria than those used by Duncan.

behavior—although we feel he is working from unsound premises—or for an analysis of the data on heredity presented by him, and by Slater (1936) who refutes him. It does, however, appear, that his group of manic-depressives is almost certainly lower than ours in general mental level, and this should be noted, although it is impossible to make direct comparisons. Certainly his conclusions are not at all in accord with ours and those of most other American workers, but whether this discrepancy results from different diagnostic criteria for the disease, differences in representativeness of psychometric results, or differences in technique, cannot be determined on the evidence available.

Slater (1936) who criticized the work of Duncan and his associates at length, and who also reported further work on inheritance stated, "The rather small evidence, then, that we have is such as to suggest a negative answer to the question 'Is there any relation between manic-depressive insanity and mental defect? ' "

PSYCHOPATHIC PERSONALITY WITH PSYCHOSIS

This group is significantly younger than the normal. The Taussig distribution does not give much information about the group as a whole, since half of them have no occupation—these are mostly younger women who had remained at home until their hospitalization. Mean test results are close, but in one instance differ significantly, *viz.*, digits forwards.

Three items showed significant differences: induction (XIV-2), president and king (XIV-3), and arithmetical reasoning (XIV-5). Two had possibly significant differences: defining abstract words (XII-2) and 7 digits forwards (XIV-7).

Curtis (1918) observed that these cases are very near the normal.

Michaels and Schilling (1936) found for 38 cases diagnosed as psychopathic personality (not distinguished as to whether they were with or without psychosis) a mean Binet of 164, somewhat higher than ours (156). The ages are not given.

Wells and Kelley (1920) reported on 8 cases of "constitutional psychopathy" whose median age was 34. Their mean Stanford-Binet score was 163.

Kendig and Richmond (1940) reported a median MA for 65 cases of psychopathic personality with psychosis of 147, 9 months lower than ours.

PSYCHOPATHIC PERSONALITY WITHOUT PSYCHOSIS

Like the preceding group, this is younger than the normal, but the educational mean is practically the same. There are six with no occupa-

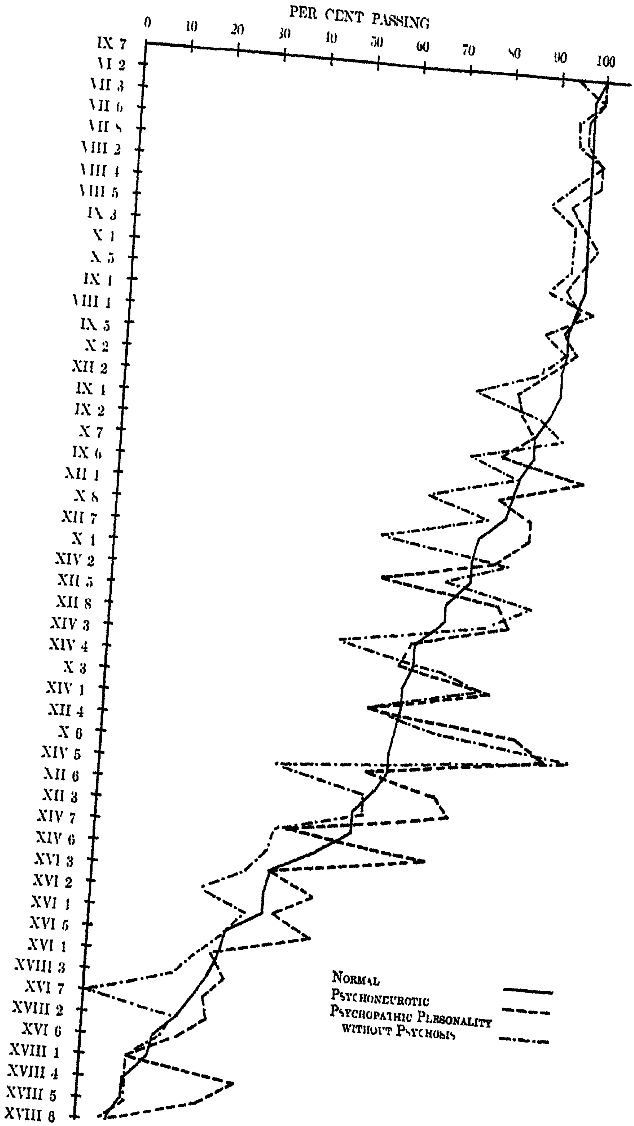

FIGURE 5. Percent passing each item: normal, representative psychoneurotic, and representative psychopathic personality without psychosis. Items arranged in order of difficulty for normals. These two groups rarely deviate markedly from the normal.

tion. All results from the Stanford-Binet approximate the normal; neither for means nor separate items is any P less than .05 (see FIGURE 5).

The 60 cases reported by Kendig and Richmond (1940) had a median MA of 147, compared with our mean of 156. It is of interest that the means for both their groups are identical as are those for our two groups, with and without psychosis.

PARANOID CONDITION

In age and education the group is very like the normal; in occupation, although they do not differ significantly, there are relatively more in the professional and fewer in the skilled labor group. Mean test results are very similar except for digits forwards which shows a difference with a P of less than .02.

This is reflected in the item analysis, the only significant difference being for 7 digits forwards (XIV-7). Free association (X-6) has a possibly significant difference with the paranoid group surpassing the normals.

The four cases included in the paper by Wells and Kelley (1920) have a mean Stanford-Binet score of 187. Michaels and Schilling (1936) found for their 15 cases diagnosed paranoid state, a mean Stanford-Binet of 156.

Jastak's (1937) 4 cases of paranoid condition had a mean Stanford-Binet score of 154, the lowest reported. Their mean vocabulary MA was 168, score 52, also lower than ours. The Kendig-Richmond median MA was 161 for 41 diagnosed as paranoid state. Our mean is 165.

PSYCHONEUROSIS

This group is younger than the normal and somewhat better educated. There were 8 with no occupations. Mean test results are all extremely close. In general, the neurotic group is slightly higher than the normal on item performances (FIGURE 5), and the difference is significant for 4 items and possibly so for 2, as listed below:

$.05 > P > .02$	$P < .02$
Designs (X-3)	Free Association (X-6)
7 Digits Backwards (XVIII-5)	Dissected Sentences (XII-4)
	Clock (XIV-6)
	Repeating passage (XVIII-4)

Prideaux (1921), in an essay on the psychoneuroses, presented percentages showing the incidence of various types at different levels of school history, noting that constitutional inferiority was found with lower grade aments, conversion hysteria more frequently among high

grade aments and anxiety and obsessional states more often among the higher groups.

Tendler (1923) has argued that the psychoneuroses occur chiefly in persons of low normal intelligence and result from the social situation engendered by this. In the present study the mean Stanford-Binet for neurotics was slightly higher than the normal, although not significantly so. Tendler found a median MA of 14.3 (172) for normals picked up here and there and a median MA of 12.0 (144) for "patients at a nerve clinic for psychoneurotic conditions." The difference was a significant one. An examination of the tests he used will clear up some of the apparent discrepancies in the findings of the two studies. These were: cancellation, dotting, rote memory, Knox cube, Marble Statue, W. & W. substitution, W. & W. hard directions, Trabue completion, number checking, free association (Pyle). Of all of these only the Trabue Completion Test would be accepted as a test of "general intelligence" (verbal). On this his normals scored a median MA of 13.6 and his neurotics one of 14.0. On the memory test (Marble Statue) their median MA's were identical—18.0. On the other tests they fell sufficiently below the normals to make the final composite median much lower. The functions he tested are certainly not those which are commonly considered as being fundamentally involved in general intelligence. Speed is of considerable importance in a number of the tests of his battery, and it is not surprising that a neurotic population should show poor achievement in this.

The sub-groups by neurotic types show interesting differences. His median MA's were: neurasthenics, 10.7; psychasthenics, 12.1; hysterics, 13.6 Insofar as speed is a factor, one would expect the neurasthenics to be most affected, and the hysterics least; the effect in the neurasthenics was apparently sufficient to pull the whole neurotic groups significantly below the normal level on the composite score. When the psychoneurotics of the present study are classified according to this same scheme, the medians for Stanford-Binet are: neurasthenic (8) 12.3; psychasthenic (3) 14.9; hysteric (16) 14.3. It is apparent that here also the neurasthenic group is lower than the hysteric (there are too few psychasthenics to consider), but it does not follow that the type of neurosis results from the original MA level of the patient. It is much more likely that the different types of neurosis affect different functions in different degrees.

Curtis (1918) mentions the hysterics and psychoneurotics as being approximately normal. Schott (1931) found that in 450 cases of all types of disorder 18 were above 120 IQ and these were chiefly psychoneurotics.

Hollingworth (1920: 88), on the basis of a number of miscellaneous tests, among which is the Stanford-Binet, reports an average MA of 12.6 (151.2) for 114 psychoneurotics. He also presents data for different types of psychoneurosis: 177 hysterics, 11.9 (142.8); 83 neurasthenics, 13.0 (156.0); 10 psychasthenics, 14.9 (178.8). This combined group of 384 subjects gives an approximate mean MA (determined from his frequency distribution) of 11.9 (142.8). It would seem that the discrepancies between Hollingworth's results and ours cannot be evaluated because of the different tests which are involved. The Hollingworth results are neither consistent with Tendler's nor with ours.

Wechsler (1929) bases a discussion of intelligence in relation to psychoneurosis on the above work of Hollingworth and Tendler. He advances the view that psychological studies have indicated that the intellectual level of psychoneurotics is lower than that of normal individuals of corresponding social and economic status. As already indicated, this is not corroborated by our findings.

At one point, he modifies this view somewhat. He indicates that the mean level of the psychoneurotics arises from a bimodal distribution, the modal points occurring at the 11-12 and 16-17 year levels. He draws the conclusion that the psychoneurotic comes from both ends of the intellectual scale rather than from the middle. Age level frequency distributions of our representative neurasthenic cases (n = 8), representative hysterics (16), representative cases of other types of psychoneurotics (12), total representative psychoneurotic (n = 36), and total nonrepresentative psychoneurotic (n = 48) give no indication of such bimodality.

A further point made by Wechsler is that psychoneurotics have a more irregular performance on the Stanford, *i.e.*, they "scatter" more than normals. A comparison of the Pressey scatter of the present group of psychoneurotics with that of a comparable group of normals (n = 51) taken from a study on scatter (Harris & Shakow 1938) gives a mean of 19.9 for the former and 18.4 for the latter, indicating an absence of such difference. In inter-individual variation, as well as in the intra-individual variation just discussed, our results do not corroborate Wechsler's statement about greater variability in the psychoneurotic. The standard deviations of our psychoneurotic and normal groups differ very little.

We have already discussed the fact that our results are consistent with Tendler's in showing hysterics to have a higher mean level than the neurasthenics. Wechsler accepts Hollingworth's result in this respect, *viz.*, "hysterics, at least, those who show conversion symptoms, have on the average the lowest mental level."

Our results, thus, do not corroborate Wechsler's conclusion from the Tendler and Hollingworth studies in either of these respects, or with regard to the type of test in which they do more poorly.

Jastak's (1937) 7 psychoneurotics had a mean Stanford-Binet score of 176, vocabulary score of 58, equivalent MA of 179. Both are higher than ours. The 26 psychoneurotics reported by Kendig and Richmond (1940) have a median MA equal to our average, *i.e.*, 169.

In an as yet unpublished study on therapeutic results in psychoneurosis, Malamud and Gottlieb* report on 256 cases, including the various types of the disorder. The mean MA level of their total group is 174.6 months on the Stanford-Binet, somewhat higher than our mean of 169.1. The difference may be accounted for by the fact that their sample was drawn from a psychopathic hospital (Iowa), an institution which is more likely to get a higher proportion of patients with good prognosis than is a state hospital. Since there appears to be a relationship between high intelligence and good prognosis in psychoneurotics (their "recovered" group had a mean of 178.2 and their "not recovered" group one of 166.2) there is some basis for this conjecture. The MA's by types are as follows: hysteria, 177; psychasthenia, 177; mixed, 173; anxiety, 172; neurasthenia, 169. These results are roughly harmonious with Tendler's and ours with respect to the lower level of the neurasthenics.

Thus with respect to level the Malamud-Gottlieb data corroborate our findings as well as those of Jastak and Kendig and Richmond and presumably those of Schott and Curtis that psychoneurotics are at least of normal level. They offer no support to the contentions of Tendler, Hollingworth and Wechsler that psychoneurotics are of below average intelligence.

WITHOUT PSYCHOSIS

This large group comprises individuals who were sent to the hospital for examination and declared without psychosis (and, by inference, not feebleminded, not neurotic, and not psychopathic). This group includes most of the adult delinquents referred by the courts for examination to determine possible mental involvement. Causes for examination of the other cases are varied; they may be summed up as involving conflict of a severe sort between the individual and the environment. The diagnosis of "Without Psychosis" implies that in the judgment of the psychiatric staff this conflict is not due to the presence in the subject of mental abnormality of a kind usually necessitating hospitalization. Although in no case was the psychiatric diagnosis "Feeblemindedness"

*We are grateful to Drs. Malamud and Gottlieb for their courtesy in giving us access to their data.

made, it is probable that there is an intellectual defect present in some of the group; it is also highly probable that a more rigid diagnostic scheme would have classified some as neurotics and some as "Psychopathic Personality without Psychosis." This group is significantly younger than the normal, but very like it in education and occupation. All mean test results are lower, vocabulary and digits forwards significantly so, and Stanford-Binet score possibly significantly so.

Chi-square analysis reveals a number of significant differences (all except for X-6, in favor of the normal): digits backwards at IX, comprehension (X-5), free association (X-6), digits forwards at X, abstract words (XII-2), vocabulary at XIV, induction (XIV-2), president and king (XIV-3), arithmetic reasoning (XIV-5), and digits forwards at XIV. Of possible significance are: digits forwards at VII, fables (XII-5), difference between abstract terms (XVI-3). The disturbance thus seems to be more concentrated on memory items, including vocabulary and to a small degree on thinking items (see FIGURE 4, page 389).

It seems apparent, from this analysis, that the occasional practice of using such a group as this as a "Normal" group for comparison with psychotic populations is decidedly unsound. They are certainly not "Normal" in the sense in which this term should be used in such a connection.

Cornell and Lowden (1923) found for 25 non-psychotic cases at the Boston Psychopathic Hospital, a median Binet of 168—apparently a non-psychotic group of much higher level than comes to a state hospital such as ours.

SUMMARY

TABLE 11 shows the groups which differ significantly from the normal in mean scores.

TABLE 11

SUMMARY OF SIGNIFICANT DIFFERENCES BETWEEN MEANS OF REPRESENTATIVE HOSPITAL GROUPS AND A NORMAL GROUP

	$.05 > P > .02$	$P \leqq .02$
St-B	WP	GP; CA+; DPH; DPU
Voc	GP	DPH; WP
DF	AA	GP; CA+; DPP; DPH; DPU; PP+; PC; WP
DB		GP; CA+; DPH; DPU

Four groups, two organic and two dementia praecox, have significantly lower means on total Stanford-Binet score. These same groups are also the only ones which have significantly lower means on digits backwards although eight of the groups are lower on digits forwards. In general, score on digits backwards seems to be rather more closely related to "general intelligence" than to rote memory*. Obviously, rote memory ability must provide an upper limit but the closeness with which this is approximated seems to be due to some other factor. The without psychosis group shows a possibly significant difference in total Stanford-Binet score, but not on digits backwards.

The situation with respect to vocabulary score is discussed in considerable detail later in this section because of the amount of recent work on the point. It suffices here to point out that this study confirms others in finding vocabulary tests relatively less often and less severely affected than are other types, but we found them not unaffected.

It is notable that 8 of the 15 groups here considered differ significantly from the normal in mean performance on digits forwards, and one shows a possibly significant difference. The only groups not affected in this respect are the catatonics (here probably a selected group as indicated above), the simple dementia praecox, the manic-depressive and the non-psychotic psychoneurosis, psychopathic personality without psychosis and chronic alcoholism without psychosis groups. In some of these it may be that there is a specific memory loss (particularly in the paretic) but this does not seem to be the case generally. In all probability the low results on digit repetition reflect a lowered attention span, particularly for material that is essentially non-meaningful, rather than a memory difficulty involving recall. These groups are not consistently lower on sentence memory. It should be noted further that in the case of the normal group, the mean digits forwards score is believed to have been artificially somewhat lowered by the presence of an end error, for on the Stanford scale no more than 8 digits are given even though the subject repeats these correctly. This error naturally exists only at the upper levels, but the result is that here the true psychotic-normal differences are probably diminished.

It has been generally observed that paretics show deficiencies in immediate rote memory, even beyond their general low level, but most investigators have not noted this in other groups; there has been, however, no very careful study on this point. Wells and Kelley (1920) thought this performance little affected. Wentworth (1923) stated that dementia praecox patients in her "a" group (deterioration to a generally

*Fry (1930) reports an r of +.736 for digits backwards and IQ in 227 male white prisoners.

low level, consisting mostly of hebephrenics) could do better on digits than sentences, and the higher ones of this group could repeat digits well above their MA level. In her "b" group (definite blocking of thought processes) she noted memory for digits forwards to be "peculiarly intact." Her comparison is with MA level of each subject and since her mean MA is 125, her findings do not necessarily contradict ours. Schwartz (1932) in reporting on the application of Babcock's test, gives for each test a figure representing the sum of the MA's of all subjects on that test expressed as the percent of the sum of their MA's on vocabulary. For repetition of digits this is 69, *i.e.*, Schwartz's dementia praecox cases were poorer at this than at vocabulary if Babcock's MA equivalents for digit repetition can be accepted.

Simmins (1933), using a "test of memory for recent impressions of words, numbers, and pictures", found that memory scores with "g" eliminated were within the normal range in all groups except paresis and epilepsy. Dearborn (1927), however, without citing any data, lists the fields in which intellectual regression is chiefly manifested and stresses as the most conspicuous and commonest of these a lowering of voluntary attention and a virtual or real lessening of the power of memory and recall. Rouvroy (1936: 525) comments among his conclusions that various authors have most frequently found disturbances in memory more marked than in other intellectual functions. The group on which he bases this generalization appears to contain only general paretics.

For readier reference, the means of our groups on digits forwards are assembled in TABLE 12. In the column for the representative groups, those whose difference from the normal mean of 6.7 has a P of .02 or less are in italics, those with a P between .05 and .02 followed by a question mark.

In general it is clear that the disorders with the severer clinical manifestations are the ones showing the greatest divergence from the normal*.

TABLE 13 lists each item for which significant differences between normal and psychotic were found, together with the groups in which these occurred. Parentheses around the symbol indicate that the difference was in favor of the hospital group. In only one item was this true of all differences—free association (X-6). In other items it occurred only for the psychoneurotic group and on one item for the paranoid dementia praecox group—memory for designs (X-3). The free association test was given to comparatively few of the normal group because it so frequently disturbed the subjects and it was noted that some of them com-

*The catatonic dementia praecox would seem to belie this, but we have already discussed the sampling situation in this group, which is somewhat different from that in the others.

TABLE 12

MEANS FOR DIGITS FORWARDS FOR REPRESENTATIVE HOSPITAL GROUPS AND THE NORMAL GROUP

	R
Normals	6.7
MD	6.7
DPS	6.6
PN	6.5
DPC	6.5
PP−	6.3
CA−	6.3
PP+	6.2
DPP	6.1
WP	6.0
PC	6.0
AA+	6.0?
DPU	6.0
CA+	5.8
GP	5.5
DPH	5.5

plained that the test made them "feel foolish". Observations of behavior seemed to indicate that the test was sometimes an index of emotional stability (Weisenburg, Roe, & McBride 1936: footnote p. 59). Dearborn (1927), in discussing results with psychotics, speaks of this item as being "rather erratic". The test was omitted frequently as a matter of policy with the patient group so that only very small groups on which to make comparisons on this item are available. Too much consideration should therefore not be given to it. Since it was generally true however, that the percent passing this item was higher for the psychopathic groups (in 11 of the 15 instances) a more careful study seems warranted.

Each item is given a discriminative value as before. In TABLE 14 the discriminative values are arranged in rank order.

The highest discriminative value for any item is 7, which appears only for 7 digits forwards (XIV-7). This reflects, as does 6 digits forwards (X-7) with a discriminative value of 5½, the definite general lower performance on this test among individuals with mental disorders which is seen in the differences in the means. Here the difference appears in only the second and third highest levels, where the distributions vary the most.

The five other tests with a discriminative value of 5 and above—

TABLE 13

SIGNIFICANCE OF DIFFERENCES ON ITEMS BETWEEN REPRESENTATIVE GROUPS AND A NORMAL GROUP

		.05>P>.02	P=.02 or less	Tally
VII-1	Fingers			0
2	Pictures			0
3	5 DF			0
4	Bowknot		DPU	1
5	Differences			0
6	Copy diamond			0
7	Days week			0
8	3 DB	WP		½
VIII-1	Ball & field	DPU	DPH	1½
2	20-1			0
3	Comprehension		DPH; DPU	2
4	Similarities	DPH		½
5	Definitions	DPH		½
6	Vocabulary		DPH	1
IX-1	Date	GP; DPU	DPH	2
2	Weights	GP; DPH		1
3	Making change			0
4	4 DB	DPP	GP; DPH; WP; DPU	4½
5	Sentence con.	CA+	GP; DPH; DPU	3½
6	Rhymes		GP; DPH	2
X-1	Vocabulary	DPP	DPH; DPU	2½
2	Absurdities		GP; CA+; DPP; DPH; DPS; DPU	6
3	Designs	DPH; DPS; (PN)*	GP; (DPP)	2 (1½)
4	Reading	DPU	GP	1½
5	Comprehension		GP; DPP; DPH; DPS; DPU; WP	6
6	Free assoc.	(DPC) (PC)	(PN) (WP)	(4)
7	6 DF	CA+	GP; DPP; DPH; DPU; WP	5½
8	Rep. 22 syll.	DPH	GP; DPU	2½
XII-1	Vocabulary	CA+	GP; DPH	2½
2	Abstr. words	CA+; PP+	DPH; DPU; WP	4
3	Ball & field			0
4	Dissect. sent.		(PN)	(1)
5	Fables	CA+; WP	GP; DPP; DPH; DPU	5
6	5 DB	CA+	GP; DPH	2½
7	Pictures		GP; DPH	2
8	Similarities		GP; DPH	2
XIV-1	Vocabulary		WP	1
2	Induction	DPP; DPC	GP; CA−; DPH; PP+; WP	6
3	Pres. & king	CA+	GP; DPP; DPU; WP; PP+	5½
4	Problems	DPP; DPU	GP; DPH	3
5	Arith. reas.	DPU	GP; DPH; PP+; WP	4½
6	Clock	CA+; DPH	(PN)	1 (1)
7	7 DF	DPP; PP+	GP; CA+; DPH; DPU; PC; WP	7
XVI-1	Vocabulary			0
2	Fables		GP; DPH; DPU	3
3	Abstr. words	WP	GP; DPH	2½
4	Enclosed boxes	DPU	GP; DPH	2½
5	6 DB			0
6	Code			0
7	Rep. 28 syll.	GP; DPH		1
XVIII-1	Vocabulary			0
2	Paper cutting		DPH	1
3	8 DF	DPH		½
4	Thought pass.		(PN)	(1)
5	7 DB	(PN)		(½)
6	Ingenuity			0

*Items in parentheses indicates difference in favor of psychotic group.

SUMMARY OF DISCRIMINATIVE VALUE OF ITEMS IN REPRESENTATIVE/NORMAL COMPARISONS

Tally	Item
7	XIV-7
6½	
6	X-2, X-5, XIV-2
5½	X-7, XIV-3
5	XII-5
4½	IX-4, XIV-5
4	(X-6), XII-2
3½	IX-5, X-3*
3	XIV-4, XVI-2
2½	X-1, X-8, XII-1, XII-6, XVI-3, XVI-4
2	XIII-3, IX-1, IX-6, XII-7, XII-8, XIV-6**
1½	·VIII-1, X-4
1	VII-4, VIII-6, IX-2, (XII-4), XIV-1, XVI-7, XVIII-2, (XVIII-4), (XVIII-5)
½	VII-8, VIII-4, VIII-5, XVIII-3
0	VII-1, VII-2, VII-3, VII-5, VII-6, VII-7, VIII-2, IX-3, XII-3, XVI-1, XVI-5, XVI-6, XVIII-1, XVIII-6

*1½ of this in favor of psychotic groups.
**1 of this in favor of psychotic groups.

induction, detection of absurdities, comprehension, fables, and president-and-king—are all tasks involving conceptual thinking (comprising half of the items of this type in the scale), a function which seems generally affected by psychosis. We are apparently here approaching the core of the psychotic's intellectual difficulties. Indeed it seems to us that, proceeding along these lines, it may well be possible to arrive eventually at a roughly reliable, objective measure of the extent of these difficulties in the individual, and perhaps a further diagnostic discrimination on the basis of them.

The items at 4½ and below distribute themselves among the various

types of functions and do not permit of clear generalization. The problem will be further considered in connection with the various diagnostic types but at this point it seems reasonable to conclude that, aside from a special difficulty with repeating digits, psychosis seems to affect primarily conceptual thinking.

Dearborn (1927) mentions derangement of conceptual association in general, frequently resulting in abolition of the power of inference, as one manifestation of intellectual regression.

Bolles (1937) in a stimulating paper reported the results of a qualitative analysis of the behavior of aments, dements and children of the same MA on various sorting tests; she found that the task of organizing a miscellaneous group of objects was pursued on different levels of abstraction. She noted that both aments and dements responded in a "concrete" way on tests in which either a "concrete" or "abstract" response was possible but that the normal children were capable of both types of behavior, and succeeded when the task necessitated abstract behavior whereas the others failed. Her groups were small and she made no attempt to check her results statistically for significance. Although we have not done so, either, the trend is clearly as she reported. The task involved is analogous to those we have designated "conceptual thinking". She did, in fact, give Binet items VII-5, VIII-4, X-2, XII-2, XII-5, and XII-8 in addition, the only one showing marked differences being X-2 (absurdities).

The number of significant item differences found for each group are tabulated below. The first figure gives the number of differences in favor of the normals; the figures in parentheses, when they occur, the number in favor of the patient group.

1. Hebephrenic D.P. 29
2. General Paresis .... $23\frac{1}{2}$
3. Unclassified D.P. 17
   [Total Dementia Praecox.... $15\frac{1}{2}$]
4. Without Psychosis 10; (1)
5. Paranoid D.P. 8; (1)
6. Chronic Alcoholism with Psychosis 6
7. Psychopathic Personality with Psychosis 4
8. Simple D.P. .... $2\frac{1}{2}$
9. Paranoid Condition .... $1\frac{1}{2}$, ($\frac{1}{2}$)
10. Catatonic D.P. .... 1; ($\frac{1}{2}$)
11. Chronic Alcoholism without Psychosis 1
12. Acute Alcoholism 0
13. Manic-depressive 0
14. Psychopathic Personality without Psychosis 0
15. Psychoneurosis 0; (6)

The paretic and the hebephrenic are types which "deteriorate" generally in the clinical sense. In the case of the chronic alcoholic with psychosis we have shown that it is apparently the psychotic process rather than the alcoholism *per se* which brings about the decrement in

function. As regards the unclassified dementia praecox and the without psychosis groups little can be said. Some similarities in test performance between these two latter groups may be noted; in both the clinical picture is a very indefinite one and the groups are probably heterogeneous.

If we consider the dementia praecox groups we find the hebephrenic affected by far the most—in fact it is the most strikingly affected of all the diagnostic groups. The unclassified group is next most affected with the paranoid following; the simple and the catatonic are relatively little affected. The paranoid dementia praecoxes are generally considered rather less disturbed cognitively than the other types, but this more extensive analysis shows them to be affected to some extent. That the catatonics in this group come so close to the normal is in one sense somewhat misleading with respect to catatonics in general. The cases included in this analysis are only those on whom a representative test could be obtained. This criterion excludes all mute and excited catatonics. Since, in general, the more severely affected catatonics are less accessible for psychometrics than the equally severely affected members of other groups, this catatonic group is relatively a selected one. On the other hand, there is also the clinical fact that catatonics have a better prognosis than any of the other schizophrenic groups.

The three alcoholic groups show relative positions which emphasize the importance of psychosis over alcoholism *per se*. Acute alcoholic psychosis shows no significant item differences though the lower mean performance on digits forwards has some degree of significance; the chronic alcoholics without psychosis fall significantly below normal on only one item; the chronic alcoholic with psychosis group, however, are in sixth place in the list, and means for Stanford-Binet score, digits forwards and digits backwards significantly lower than the normal.

The paretics are second on the item list with, in addition, four significantly lower means, a fact which reflects the generalized disturbance in this group.

The position of the without-psychosis group, fourth on this item list, with significantly lower performances on vocabulary, digits forwards and a possibly significantly lower mean Stanford-Binet score, is rather surprising at first glance. The nature of the items showing differences as well as the definitely lower vocabulary score gives weight to the suspicion of a poorer group with regard to general intelligence. If one adds to this the great heterogeneity of the group with its almost certain inclusion of borderline psychopaths as well as persons below normal intellectually, its position becomes more reasonable.

The psychoneurotic group shows no significant mean differences and in number of significant item differences is at the extreme of the distribution since all of these differences are in their favor. The manic-depressive group is in no instance significantly different from the normal. The two psychopathic-personality groups distinguish themselves somewhat. The group with psychosis differs significantly in mean for digits forwards only and ranks seventh in item differences with a tally of 5. The group without psychosis does not differ significantly from the normal either in means or in any of the items. The paranoid condition group ranks with the catatonics; it has one significant mean difference—digits forwards—and an item tally of one.

It is of some interest to know the ways in which these differences distribute themselves. TABLE 15 gives for the different diagnoses the number and percent of items of different types which show significant differences ($P = < .05$) in favor of the normal group. Considering only those groups which have been affected in some way it will be seen that the paretic group is predominantly affected in conceptual thinking and immediate memory with some scattering effect on other types of functions. Chronic alcoholism with psychosis is more or less evenly affected in all functions in a relatively mild degree. Among the dementia praecox groups, the hebephrenic is affected generally, but particularly in conceptual and sustained associative thinking and vocabulary. The paranoid is primarily affected in conceptual thinking, and the unclassified more or less evenly affected in all categories, with some predominance of conceptual thinking. Psychopathic personality with psychosis shows an effect in conceptual and sustained associational thinking. The without psychosis group is primarily affected in conceptual thinking, immediate memory and vocabulary.

Vocabulary and General Test Performance

Since some special problems arise in connection with vocabulary, the present section has been reserved for a discussion of the relationship between vocabulary and general test performance.

There is an increasing tendency to view the score on vocabulary tests as a comparatively accurate indicator of the original mental level of psychotic subjects, and the extent of divergence from this level on other tests as, approximately, the extent of deterioration. Babcock's work is well known and will not be discussed in detail here. There are a number of studies following and, for the most part, confirming hers. A few of these may be briefly mentioned.

Schwartz (1932) followed Babcock's technique although he expresses

TABLE 15

PERCENTAGE OF ITEMS OF DIFFERENT TYPES SHOWING SIGNIFICANT DIFFERENCES*
IN REPRESENTATIVE/NORMAL COMPARISONS

	LRV (8)		LRO (10)		LI (15)		TAI (7)		TAS (11)		TC (10)		Total
	N	%	N	%	N	%	N	%	N	%	N	%	
GP	1	13	1	10	9	60	2	28	4	36	8	80	25
CA+	2	25	0	0	3	20	0	0	2	18	3	30	10
CA−	0	0	0	0	0	0	0	0	0	0	1	10	1
AA	0	0	0	0	0	0	0	0	0	0	0	0	0
DPP	1	13	0	0	3	20	1	14	0	0	5	50	10
DPH	5	63	1	10	9	60	3	43	7	64	8	80	33
DPC	0	0	0	0	0	0	0	0	0	0	1	10	1
DPS	0	0	0	0	1	7	1	14	0	0	1	10	3
DPU	2	25	2	20	4	27	2	28	4	36	5	50	19
DP	2	25	2	20	5	33	2	28	2	18	5	50	18
MD	0	0	0	0	0	0	0	0	0	0	0	0	0
PP+	0	0	0	0	0	0	0	0	2	18	1	10	3
PP−	0	0	0	0	0	0	0	0	0	0	0	0	0
PC	0	0	0	0	1	7	0	0	0	0	0	0	1
PN	0	0	0	0	0	0	0	0	0	0	0	0	0
WP	2	25	0	0	4	27	1	14	1	9	4	40	12

*Items where difference is in favor of psychotic group are omitted.

his results rather differently. He concluded, "This test, when found to be scientifically sound, may be profitably used as an auxiliary criterion to differentiate amentia from dementia and benign mental processes from malign mental afflictions."

Wittman (1937), in a somewhat uncritical study on 215 patients, some of whom were retested, found Babcock's test of value, and stated that her results tended to corroborate Babcock's use of the vocabulary scale.

Both Simmins (1933) and Harbinson (1936) have measured deterioration of 'g' by the discrepancy between scores on 'g' tests and vocabulary tests in psychotics. In another paper Simmins (1935) states, "It is probable that the vocabulary scores of patients suffering from general paralysis of the insane cannot be accepted at their face value as measures of earlier intelligence".

Davidson (1937) calculated the discrepancies between the vocabulary scores (MA equivalents of score on first list converted by a table, of unspecified origin, differing slightly from that given by Terman) and the Stanford-Binet scores of 71 schizophrenics, comparing them with "a control group of 202 normals of similar age range" (no further specification). Her normals were 3 months higher on vocabulary than on Stanford-Binet, her schizophrenics 30 months. Retests on deteriorating schizophrenics and non-deteriorating manic-depressives showed an increase in the discrepancy score in the first group, but not in the second. In a later study, her group of manic-depressive patients had a mean vocabulary MA 25 months higher than the Binet MA, and the schizophrenics a mean vocabulary MA 47 months higher than the Binet MA. When she sub-divided the groups by age, she found the discrepancies to be greater in the older groups.

Jastak's study (1937) compares mean Stanford-Binet IQ, vocabulary IQ (based on his norms for children) and Army Individual Performance Scale Quotient for 100 patients in various diagnostic groups. In all of the psychoses, what he calls the "hospital pattern," *i.e.*, mean vocabulary IQ highest, Stanford-Binet IQ next and performance IQ lowest, appears; in the without psychosis group, the vocabulary is again highest but performance quotient is next. For the total psychotic group, discrepancies between the quotients are all significant (D/σ_D 3.0). He does not consider what these relations are in a normal group. Further his control group is one diagnosed without psychosis and such material does not provide an acceptable reference group. It is clear, too, as will be shown in detail later, that it is generally true in normal adults that vocabulary MA by current equivalents is higher than total Stanford-Binet MA. Until proof is adduced from a satisfactory control

group one must accept with caution Jastak's assumption that in a normal group performance achievement runs at a higher level than does Stanford-Binet achievement.

Altman and Shakow (1937) made such comparisons between matched groups of schizophrenics, normals, and delinquents. Their technique of comparison is relatively elaborate and not readily comparable to other studies, but they establish a reliable difference between the higher discrepancy score (sigma scores) of schizophrenics and those of normal subjects and delinquents of the same MA.

Wechsler (1939) in analyzing the performance and verbal portions of the Bellevue Intelligence Test found a median IQ difference for ages 20 to 49 of 8.4, and that in IQ ranges below normal the performance IQ tended to be higher than the verbal. The reverse held for the IQ ranges above normal and to about the same extent. These results are very suggestive and indicate the need for further careful research.

Kendig and Richmond (1940) give median Stanford-Binet and vocabuary mental ages for various groups. These are tabulated below:

	N	Median Stanford-Binet	Median Vocabulary
Nurses	217	15–1	15
Employees	129	13–0	12
DP Total White	429	11–11	12
Hebephrenic	32	11–6	10
Simple	14	10–7	9
Catatonic	51	12–0	12
Paranoid	41	12–4	12
Paranoid Condition	41	13–5	15

Unfortunately, median vocabulary is reported in terms of years and meidan Stanford-Binet in terms of years and months, so that it is not possible to make accurate comparisons. Apparently, however, the hebephrenic and simple are lower on vocabulary and the paranoid condition higher.

It seems to be generally true in psychotics, that performance on such vocabulary tests as the one included in the Stanford-Binet is higher, by current MA equivalents*, than performance on other tests of mental functioning although this is not so invariably true, as, for example,

*The present is not the occasion for an extensive discussion of the fallacies inherent in the system of expressing adult scores in terms of MA, although they largely and specifically affect all work of this sort. In our opinion, the use of a standard of reference from a different universe throws considerable doubt on the work that has been done on adults. We must consider, too, the further factor that age, within the limits of maturity, apparently affects vocabularly little (Shakow & Goldman) but does affect other performances, such as analogies, performance and memory tests, adversely. It is possible that a considerable part of the greater discrepancy which Babcock has found between vocabulary and her other tests (largely memory items) in general paretic and dementia praecox groups when compared with normal subjects, may be accounted for by the lower chronological age which one estimates her standardization group to have had.

Rouvroy (1936) implies. But it seems not to have occurred to most investigators to make certain first whether this is not also the case among normals. In fact, there is considerable evidence that, by these same MA standards, there is also a discrepancy in the same direction among normal adults, although it seems to be of lesser extent. Before one can make any legitimate deductions about this relationship among psychotics its limits among normals must be known.

Fry (1930), reporting on adult prisoners, found a mean MA of 155 on the Stanford-Binet, and a vocabulary score of 52 which has a Terman equivalent of 170. Shakow and Millard (1935) in a study of 150 adult delinquents, reported a mean MA of 149 and a vocabulary score of 51, which is equivalent to an MA of 168. Delinquents do not comprise an ideal "normal" group, of course, but the results are of some corroborative value. In the Kendig-Richmond study, results for nurses were the same, but the employees were lower on vocabulary. The ages of these groups are not known.

In the normal group used in the present study, the mean Stanford-Binet score was 164, and the vocabulary 51.5, which has an MA equivalent of 175. Davidson's normals were three months higher on vocabulary, as noted above, but it should be noted also that, she used only the first list, which might affect the results, although perhaps to no great extent. The 86 normals in the study by Altman and Shakow (1937) mentioned above, had a mean MA of 151 and a mean vocabulary score of 46, equivalent to an MA of 156. Their 56 representative delinquents had a mean Stanford-Binet MA (without vocabulary) of 157 and vocabulary of 51.4, equivalent to an MA of 169.

Not only is it clear that among normals, vocabulary MA is usually higher than Stanford-Binet MA but there are some indications that the amount of the discrepancy varies with chronological age. Vocabulary score in adults is comparatively little affected by age until late maturity. This is true of very few other tests and hence it is inevitable that, by the usual MA conversion system, the discrepancy between the results on the tests increases with increasing age. The data for the decades in the normal group used here are given below:

Age Range	N	ST-B Voc Mean	Terman MA Equiv.	Total St-B MA	Dis-crepancy
20–29	15	52	170	166	4
30–39	21	57	180	173	7
40–49	13	56	178	160	18
50–59	13	56	178	151	27

The groups are small, but the trend is very clear, and the discrepancy in the fifties is as great as that of the highest of our psychotic groups from the normal.

If we arrange our groups by mean age, and note the amount of the discrepancy between vocabulary MA (Terman and Babcock equivalents) and total Stanford-Binet MA, we have the data presented in TABLE 16.

TABLE 16

RELATIONSHIP BETWEEN CHRONOLOGICAL AGE AND DISCREPANCY BETWEEN TERMAN AND BABCOCK VOCABULARY MENTAL AGE EQUIVALENTS IN REPRESENTATIVE AND NORMAL GROUPS

Group	Mean CA	Discrepancies	
		Terman	Babcock
PP+	24	7	10
PP−	25	8	10
DPC	25	15	9
WP	26	8	12
PN	28	4	2
DPU	28	22	24
DPH	29	17	27
DPS	31	16	15
DPP	34	23	18
MD	35	18	11
Normals	36	11	8
PC	40	19	12
AA	40	22	18
GP	41	27	31
CA−	42	20	17
CA+	44	19	22

The rank correlation between mean age and discrepancy by Terman equivalents is +.72, by Babcock's equivalents +.59. By either, it is certain that there is considerable relationship between the measure and chronological age, and this must be discounted before valid conclusions can be drawn.

It seems reasonable then that part of the discrepancy found in certain psychotic groups may be accounted for on the basis of the inadequacy of the MA equivalents and the varying effects of age on different tests. Nevertheless there does seem to be a residue associated with psychosis. Before accepting the latter as the explanation for this remaining discrepancy, however, another factor must be considered. This is the possibility that the discrepancy itself may have an inverse relationship to Binet score. If such a relationship should exist, the greater discrep-

ancy in disordered subjects would, at least in part, be accounted for since there is a greater frequency of lower scores in these groups than in normal subjects.

The only study, to our knowledge, which has taken this factor into consideration is that of Altman and Shakow. They find (1937: 527) a "slight trend which ....indicates that the subjects with the lowest MA show relatively better vocabulary performance than other subjects, and *vice versa*." (The correlations run from −.10 to −.50). Some part of the remaining discrepancy is then probably to be accounted for by this relationship with score.

There is reason for believing, however, that the final residue of discrepancy may with some justification be related to psychosis. This may have either of two bases. The relatively greater vocabulary achievement may be due to the fact that the psychotic continues to cling to verbal contact with the universe as a last support when other—more concrete—relationships with it have been abandoned. This might tend to keep the vocabulary level up even when other aspects of mental functioning have suffered. The other, and perhaps more reasonable, hypothesis is that vocabulary is one of the most stable of functions (*cf.* Shakow & Goldman) and is as little affected by psychosis as by age. It is also a test, as Jastak (1937) has pointed out, which has a large number of items, thus giving the subject more opportunity for achieving his real level.

There is still another explanation which should be given consideration. It may possibly be that the relatively lower standards for acceptable achievement on the vocabulary test fit in best with the psychotic's generally lowered efficiency. He is therefore less penalized by the approximate answers which he is likely to give and which this test accepts. This results in an apparent—but spurious - superiority in performance over that in other types of tests. The cogency of this argument could be determined rather simply by administering vocabulary tests involving different degrees of stringency of definition.

It seems reasonable then to conclude that only part of the discrepancy, undetermined in amount, found in favor of vocabulary in psychotic groups is to be accounted for by psychosis. The other parts are to be accounted for by unsatisfactory MA equivalents and scoring systems, by age and by depression of mental level.

Throughout the above discussion the generally accepted notion of the adequacy of vocabulary as an indicator of original mental level has been taken at its face value. Certain of our results would raise grave doubts as to the validity of this assumption. Obviously, the most satisfactory

test of the adequacy of vocabulary for this purpose would be to compare vocabulary scores with test scores obtained before the onset of psychosis. Since these are almost never available, we may, for purposes of discussion, accept the only measure of pre-psychotic performance which *is* available to us, *i.e.*, educational level, despite the fact that the unsatisfactory nature of this measure also cannot be denied. In addition to the considerable variation of school standards both in time and place, numerous other objections could be raised. Because of these objections there is little justification for using this measure in the case of the individual. There is considerably less objection to its use for groups, however, since there is no reason to believe that a systematic error of any degree of importance is introduced.

For the purpose of the present argument the educational ratings are converted to MA equivalents* and compared with the vocabulary equivalent. It seems reasonable to believe that any tendency towards the raising of the educational level, whether due to automatic rather than earned promotions or to any other cause, would be compensated for by cases in which the psychosis must have started early with its probable deterrent effect on school achievement. If anything, the latter probably plays a greater role than the former so that the school attainment indicated by the means may with some justification be taken as conservative.

TABLE 17 gives the equivalent MA ratings for vocabulary and education, the discrepancies between these measures and between them and MA. It will be noted that there are two marked cases of discrepancy in favor of the educational equivalents: hebephrenic, 28 months, and general paresis, 16 months. (The discrepancies in the two feebleminded groups are not considered since the problem at this low MA level is probably quite different). This would indicate that in the case of these rather severe psychoses the vocabulary level, while a better indicator of original endowment than Stanford-Binet score, is still probably far from an adequate indicator of this level.

For purposes of comparison with other studies we have also presented in TABLE 17 the MA equivalent of vocabulary by both Terman's (1925: 25) and Babcock's (1930) tables**. Note that in every instance the vocabulary mean is the higher. It must be remembered that vocabulary

*Since the educational constants used in this study refer to grades completed the equivalent is determined by adding 6 to these means. A slight error creeps in, due to the fact that no correction is made for the shifting of educational standards which has occurred with the passage of time. However, since none of the means for chronological age is over 44 years, the error is believed to be sufficiently small so as not to invalidate the argument, which with the data at our command can in any case be established only very roughly.

**Babcock started with Terman's table, but she apparently thought the equivalents too low at the lower levels and too high at the upper ones, so she revised the norms to meet these deficiencies. She does not however state the basis for her revision. It is this revised table of norms which she uses to get her efficiency index.

score is included in total Stanford-Binet score increasingly as the levels rise, and that, since vocabulary is generally higher, the differences noted in the table are artificially lessened.

By either conversion it is apparent that, generally, organically based psychoses show the greatest differences, then the dementia praecox, and then the more benign varieties. Note the reversal of position of the paranoid and hebephrenic dementia praecox groups for the two sets of norms. This is due to the fact that from Babcock's manipulation of the Terman norms it inevitably results that those with higher vocabulary scores are heavily penalized, and that those with lower scores are favored, although the difference is less at the lower end.

In summary, it seems legitimate to conclude that there is in all groups a discrepancy between vocabulary and other scores favoring the former. This discrepancy in the case of the psychotic (particularly the schizophrenic, in whom it is greatest) may be accounted for in several ways. A certain proportion is due to the intrinsically greater difficulty, by Terman standards, of other tests compared with vocabulary. A certain proportion is probably due to the generally lower functional mental level of many psychotics (especially schizophrenics) and since there is some degree of inverse relationship between discrepancy and MA level, the discrepancy would be greater in such groups. The relatively more lenient scoring and the greater number of items in the vocabulary test may also be factors. In some groups, age plays an important role. But there is, finally, a residual discrepancy which does seem to be associated with psychosis. This is of two kinds: (1) where there is no apparent reduction of vocabulary but some effect on other tests; (2) where there is an effect both on vocabulary and on other tests but relatively greater on the latter. Examples of the second are the hebephrenic and paretic groups. It may be that it is only in cases such as the latter that one is justified in suspecting "deterioration".

Variation

There has been considerable discussion, especially in the British literature (Thomson 1932), of the problem of the variation in IQ distributions. TABLE 18 presents standard deviations of both Binet scores and IQ's for the various diagnostic groups and for the normal group*. It will be noticed that the standard deviation of our normal group is 15.3 (in points of IQ for comparison with the discussion in the literature): a standard deviation of 15 has been accepted rather generally for children. Except for the feebleminded groups, which are not legitimately comparable, and

*IQ's have been computed on the basis of 100 for the normal group.

TABLE 17

COMPARISON OF MENTAL AGE EQUIVALENTS OF EDUCATION AND VOCABULARY SCORES IN REPRESENTATIVE AND NORMAL GROUPS

	Achievement			MA Equivalents			Differences			
	Educ. Level	Vocab. Score	St. B. Score (MA)	MA equiv. Educ.	MA equiv. Vocab. (Terman)	MA equiv. Vocab. (Babcock)	D Educ. equiv.−MA	D Educ. equiv.−Voc. equiv.	D Vocab. equiv. Terman−MA	D Vocab. equiv. Babcock−MA
N	8.1	54.5	164	169	175	172	5	− 6	11	8
GP	8.6	47.4	132	175	159	163	43	16	27	31
CA+	6.9	49.9	146	155	165	168	9	−10	19	22
CA−	7.2	54.5	155	158	175	172	3	−17	20	17
AA	8.7	54.9	154	176	176	172	22	0	22	18
DPP	8.5	56.1	155	174	178	173	19	− 4	23	18
DPH	8.5	42.0	129	174	146	156	45	28	17	27
DPC	9.9	57.0	165	191	180	174	26	11	15	9
DPS	9.0	53.1	156	180	172	171	24	8	16	15
DPU	8.4	50.1	144	173	166	168	29	7	22	24
MD	8.8	58.7	166	178	184	177	12	− 6	18	11
PP+	7.6	48.9	156	163	163	166	7	0	7	10
PP−	7.8	49.2	156	166	164	166	10	2	8	10
PC	9.1	58.8	165	181	184	177	16	− 3	19	12
PN	9.4	53.7	169	185	173	171	16	12	4	2
WP	7.7	48.0	153	164	161	165	11	3	8	12
FM+	4.8	22.7	94	130	107	123	36	23	13	29
FM−	5.8	26.0	104	142	113	128	38	29	9	24

two diagnostic groups (chronic alcoholism without psychosis and paranoid condition) which have practically the same standard deviation as the normal, the psychopathic groups are all found to show greater variation in IQ than the normal group although not all are equally significant. The groups having a P of $<.02$ for differences in variation from the normal are the total unclassified and the paranoid dementia praecox groups and the group without psychosis; those with a $P<.05$ and $>.02$ are general paresis and hebephrenic dementia praecox.

TABLE 18

VARIATION OF THE REPRESENTATIVE AND NORMAL GROUPS ON THE STANFORD-BINET

Group	N	Score		IQ	
		Mean & S.E.	S.D. & S.E.	Mean	S.D.
N	65	163.6±3.1	25.0±2.2	100.0	15.3
GP	35	132.1±5.4	31.3±3.8	80.6	19.1
CA+	30	145.9±5.4	29.2±3.8	89.0	17.8
CA−	12	155.3±6.9	24.0±4.9	94.7	14.6
AA	17	154.2±7.9	31.5±5.6	94.1	19.2
DPP	58	154.8±4.4	33.5±3.1	94.4	20.4
DPH	32	129.4±5.4	30.0±3.8	78.9	18.3
DPC	30	164.8±5.3	29.1±3.8	100.5	17.8
DPS	22	155.5±7.1	32.1±5.0	94.9	19.8
DPU	38	144.0±5.9	35.6±4.1	87.8	21.7
DP	181	149.8±2.6	34.5±1.8	91.1	21.0
MD	19	166.4±7.5	32.0±5.3	101.5	19.5
PP+	22	156.1±6.1	29.1±4.5	95.2	17.9
PP−	21	156.4±6.9	30.8±4.9	95.4	18.8
PC	22	164.7±5.5	25.1±3.9	100.5	15.3
PN	36	169.1±4.8	28.5±3.4	103.2	17.4
WP	72	152.7±4.0	33.1±2.8	93.1	20.4
FM+	60	101.8±3.9	18.6±2.7	62.1	11.3
FM−	27	102.7±3.8	18.1±2.7	62.6	11.2

It is thus seen that psychosis or psychopathy tends to increase the variation of a group—this is especially true of the dementia praecox groups. This finding has already been brought out in a number of studies on schizophrenics, both psychological and physiological (Shakow & Huston 1936; Huston, Shakow, & Riggs 1937).

Ranges, means, and standard deviations of these groups on Stanford-Binet score and on vocabulary score are shown in graphic presentation in FIGURES 6 and 7. The groups in each instance are arranged in order of

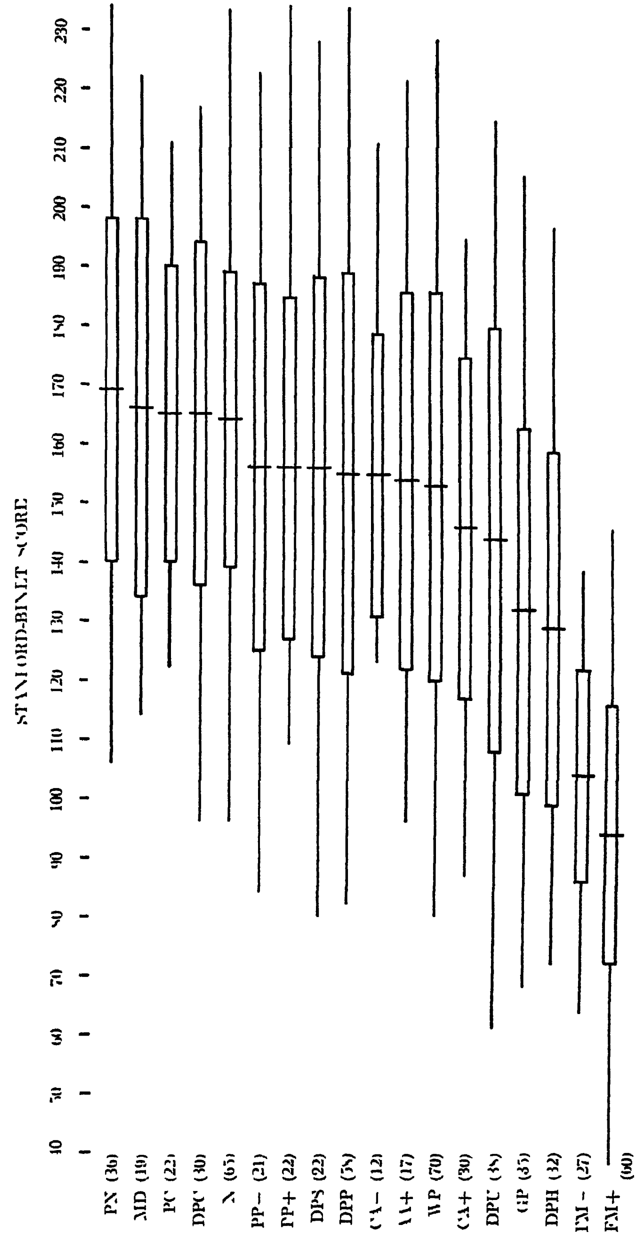

FIGURE 6. Stanford-Binet score: range, mean, and standard deviation. All representative groups and the normal. Figures in parentheses represent the number of cases in each group. The single line shows the range, the vertical line the mean, and the double line one standard deviation on either side of the mean.

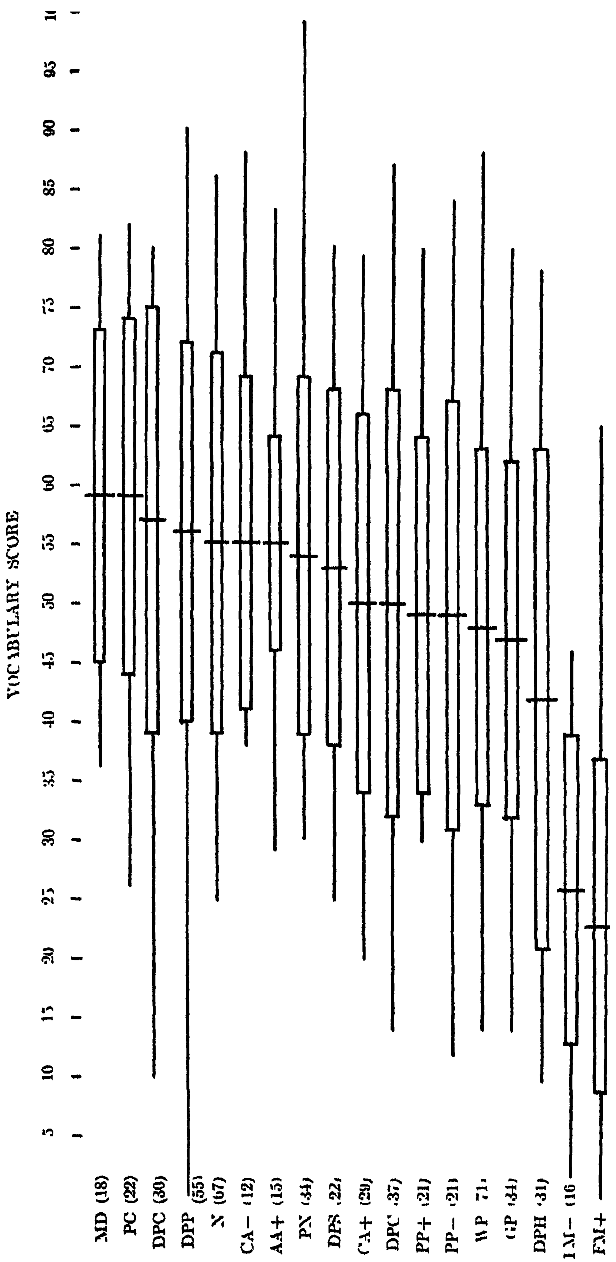

FIGURE 7. Vocabulary score: range, mean, and standard deviation. All representative groups and the normal. Figures in parentheses represent the number of cases in each group. The single line shows the range, the vertical line the mean, and the double line one standard deviation on either side of the mean.

decreasing mean score, the vertical bar indicates the mean, the solid line includes one standard deviation laid out on either side of the mean.

In FIGURE 6, Stanford-Binet score, the first 14 groups overlap extensively; the two feebleminded groups are clearly distinct, and the position of the paretic and hebephrenic groups between the feebleminded and the others is clearly shown.

In FIGURE 7, vocabulary score, the general picture is similar although the paretic and hebephrenics are a little closer to the others. It is interesting to note the considerable skew which appears in several of these groups due to an aberrant case in each. This phenomenon does not occur markedly on Stanford-Binet score, probably because of the much larger number of items as well as their variety. Ranges, on the whole do not differ more from the normal group than would be expected from differences in size and sampling*.

Correlations

TABLE 19 gives for the normal, and for each hospital group of sufficient size, N, r, z**, and S.E.z for six pairs of variables.

For the normals, the correlation between MA and CA is −.18. For these groups it ranges from −.28 (simple dementia praecox) to +.31 (catatonic dementia praecox). None of these is significant in itself, and there seems no general pattern. The sign tends to be positive with the younger and negative with the older groups. The relatively high positive correlation in the catatonic group is almost certainly a function of the smaller age range—the group includes no persons over 40—and the possibly significant difference between this and the normal group (.05 > P > .02) may therefore be discounted.

The normal MA/education correlation is +.62. These groups vary around the normal from +.47 (unclassified dementia praecox) to +.72 (hebephrenic), none of their z's differing significantly from the normal z. Again the extreme positions are held by two dementia praecox groups, but the striking thing is the consistency of the results in all of the groups.

For the normals there is a slight positive correlation between vocabu-

*Note that the influence of size of the sample on the relationship between standard deviation and range (*i. e.*, the smaller the sample, the larger the standard deviation in proportion to the range) is quite apparent in this type of graph.

**For discussion of z, see Simpson and Roe (1939: 237). Fisher presents an extensive table for the transformation of r to z. The distribution of z departs much less from normality than that of r; it is nearly constant in form and $S.E._z$ is simpler $\left(S.E._z = \frac{1}{\sqrt{N-3}}\right)$, and practically independent of the value of the correlations in the given sample. While r varies between ± 1, the limits of z are ∞ although it rarely goes beyond ± 3 in practice (equal to an r of ±.995). Below an r of about ±.5, z and r are practically equal, but at the higher levels z has increasingly smaller steps. Note the effect in the correlations between vocabulary and MA. Discussion in the text is largely confined to r since this is the better known measure, although estimates of significance of differences have been made on z.

lary and CA, +.16. Again for the psychotics, with two exceptions, the figures are remarkably close, from +.01 to +.24. The others are +.44 for the catatonics and −.11 for the unclassified dementia praecox groups —the two about equally distant from the normal. The differences are not statistically significant, and are undoubtedly related to the limited age range in each—there being no catatonic and only 3 unclassified dementia praecox over 40.

Vocabulary and MA (which includes vocabulary) seems the most consistent of all, the r's ranging from +.76 (psychoneurosis) to +.92 (paranoid dementia praecox) with the normal at +.81. The z's show the differences much more clearly, and, in fact, that between paranoid dementia praecox and normal is a significant one ($p<.02$). The Stanford-Binet is, of course, a predominantly verbal test, and this high correlation is of considerable interest in the light of the tendency of the paranoid to verbalization.

The normal vocabulary/digits forwards correlation is +.27, the psychotic ranges from +.25 (simple dementia praecox) to +.67 (chronic alcoholic with psychosis). The tendency to higher correlation for these two variables is a consistent one but only the z for CA+ differs from the normal with possible significance ($.05>P>.02$).

The vocabulary/digits backwards correlation for the normals is +.38*; the psychotic groups range from +.39 (paretics) to +.66 (without psychosis); again, the tendency is to higher correlation. Only the largest difference (without psychosis/normal) is of possible significance ($.05>P>.02$), but it is interesting that the three most divergent are the without psychosis, and the unclassified and hebephrenic dementia praecoxes, and that the feebleminded with psychosis (not included here) give a scatter diagram for these variables very like the ones for these groups.

In the case of the vocabulary/digits forwards and the vocabulary/digits backwards correlations, the groups do not seem to be in any particular order.

COMPARISONS BETWEEN DIAGNOSTIC GROUPS

In this chapter the normal group will be disregarded and comparisons will be made between various of the hospital groups. It is possible to compare each group with every other one, but only certain of the comparisons are of real import for differential diagnostic and other reasons. The comparisons fall rather naturally into three sets: (*a*) between groups with disorders having some similarity but of different degrees of severity

*Fry (1930) found this to be +.478 for 227 male white prisoners.

TABLE 19

CORRELATIONS IN REPRESENTATIVE AND NORMAL GROUPS

		MA and CA	MA and Ed	Voc and CA	Voc and MA	Voc and DF	Voc and DB
N	(n) r z ± S.E.z	(65) −.18 −.18 ± .13	(61) +.62 +.72 ± .13	(69) +.16 +.16 ± .12	(65) +.81 +1.14 ± .13	(63) +.27 +.28 ± .13	(63) +.38 +.40 ± .13
GP	(n) r z ± S.E.z	(35) +.13 +.14 ± .18	(33) +.62 +.72 ± .18	(34) +.17 +.17 ± .18	(34) +.86 +1.28 ± .18	(33) +.33 +.34 ± .18	(34) +.39 +.41 ± .18
CA+	(n) r z ± S.E.z	(30) +.48 +.24 ± .19	(29) +.59 +.67 ± .20	(29) +.24 +.24 ± .20	(29) +.87 +1.34 ± .20	(29) +.67 +.81 ± .20	(29) +.54 +.60 ± .20
DPP	(n) r z ± S.E.z	(57) −.02 −.02 ± .11	(56) +.67 +.81 ± .14	(55) +.13 +.13 ± .14	(55) +.92 +1.62 ± .14	(55) +.46 +.50 ± .14	(55) +.46 +.50 ± .14
DPH	(n) r z ± S.E.z	(29) −.12 −.12 ± .20	(29) +.72 +.91 ± .20	(26) +.06 +.06 ± .21	(27) +.83 +1.20 ± .20	(27) +.37 +.39 ± .20	(27) +.57 +.64 ± .20
DPC	(n) r z ± S.E.z	(30) +.31 +.32 ± .19	(28) +.61 +.71 ± .20	(30) +.44 +.47 ± .19	(31) +.85 +1.25 ± .19	(30) +.42 +.45 ± .19	(31) +.44 +.48 ± .19
DPS	(n) r z ± S.E.z	(22) −.28 −.29 ± .23	(22) +.53 +.59 ± .23	(22) +.01 +.01 ± .23	(22) +.80 +1.09 ± .23	(22) +.25 +.26 ± .23	(21) +.49 +.54 ± .24
DPU	(n) r z ± S.E.z	(37) −.24 −.24 ± .17	(35) +.47 +.51 ± .18	(36) −.11 −.12 ± .17	(36) +.89 +1.41 ± .17	(36) +.53 +.60 ± .17	(36) +.63 +.75 ± .17
PN	(n) r z ± S.E.z	(36) −.26 −.26 ± .17	(36) +.52 +.57 ± .17	(34) +.14 +.14 ± .18	(34) +.76 +.99 ± .18	(34) +.44 +.47 ± .18	(34) +.44 +.47 ± .18
WP	(n) r z ± S.E.z	(72) −.03 −.03 ± .12	(72) +.53 +.59 ± .12	(71) +.18 +.19 ± .12	(71) +.83 +1.18 ± .12	(71) +.36 +.38 ± .12	(71) +.66 +.78 ± .12

—in certain instances the distinction being the presence or absence of psychosis; (*b*) between groups of disorders alike because of a presumable organic basis, and between an organic and functional disorder; (*c*) comparisons among the various types of dementia praecox.

The first set includes: (1) the alcoholic groups; (2) psychopathic personality with and without psychosis; (3) feeblemindedness with and without psychosis; (4) paranoid dementia praecox and paranoid condition; (5) psychopathic personality without psychosis and psychoneurosis; (6) manic-depressive and catatonic dementia praecox. The second set comprises comparisons of paretic with psychotic and non-psychotic feebleminded, psychotic chronic alcoholic and hebephrenic. In all instances the groups include only representative examinations as in the preceding section.

Comparisons between Groups with Similar Disorders

THE ALCOHOLIC GROUPS

Chronic alcoholism with and without psychosis, and acute alcoholic psychosis:

	Means					
	Age	Ed	St-B Score	Voc	DF	DB
Chronic Alcoholism with Psychosis	44	6.9	146	50	5.8	4.1
Chronic Alcoholsim without Psychosis	42	7.2	155	55	6.3	4.5
Acute Alcoholic Psychosis	36	8.7	154	55	6.0	4.5

Comparisons of these three types of alcoholism indicate the acute alcoholics to be the youngest, and the psychotic chronic alcoholics oldest, as might be expected. In amount of education the positions are reversed. Of these differences, only the largest age difference is significant.

Except for the large group of semi-skilled laborers in the non-psychotic chronic alcoholic group, the Taussig distributions are similar.

No difference between mean test results is significant; that for psychotic chronic and acute alcoholic on Stanford-Binet score has a P between .05 and .02. The difference between these groups in education has a P just greater than .05, but it should be noted that the occupational distributions are extraordinarily close; the educational difference may reflect differences in educational standards as affected by age.

Item by item comparison reveals no surely significant differences for the three pairs, and only two possibly so: the non-psychotic chronic alcoholics surpass the psychotic on problems of fact (XIV-4), and the

acute alcoholics surpass the psychotic chronic on dissected sentences (XII-4). In general non-psychotic chronic and the acute alcoholic performances are very similar on both means and individual items, the psychotic chronic group tending to fall everywhere below these.

Despite the paucity of significant differences, the findings are remarkably consistent in indicating that psychosis is associated with deleterious effect on performance. Although the non-psychotic chronics are closer to the psychotic chronic in both age level and educational level, in performance on the test they are practically indistinguishable from the acute alcoholics.

It does not appear that it is the period of alcoholic indulgence which is here involved since chronicity of presumably the same approximate degree is not associated with the same effect on the non-psychotic. Neither does it seem to be a matter of original mental level since the only index of original level we have—education—is the same in both chronic groups. One is therefore forced to fall back on the hypothesis of personality defects which are brought to the surface by differences in alcoholic tolerance. In one case, that of relatively low tolerance, a psychosis develops with the concomitant effect on test achievement. In the other, in which high tolerance is apparently the rule, no psychosis develops, and hence there is practically no effect on test achievement.

PSYCHOPATHIC PERSONALITY WITH AND WITHOUT PSYCHOSIS

	Means					
	Age	Ed	St-B Score	Voc	DF	DB
With Psychosis.................	24	7.6	156	49	6.2	4.8
Without Psychosis..............	25	7.8	156	49	6.3	4.7

The correspondence between these groups is extraordinarily close in age, education and mean test results. Taussig distributions show a preponderance of the psychotic in class IV and of the non-psychotic in class V—largely a reflection of differences in the proportions of the sexes in the two groups. Although the differences are slight, it is to be noted that the non-psychotic group has always a higher standard deviation than the other. There were no significant differences on items and only two items—both involving conceptual thinking—show differences of possible significance: fables (XII-5) and induction (XIV-2); on both of these the non-psychotic surpasses the psychotic group.

Kendig and Richmond (1940) reported the same median MA for these two groups.

FEEBLEMINDEDNESS WITH AND WITHOUT PSYCHOSIS

	Means					
	Age	Ed	St-B Score	Voc	DF	DB
With Psychosis.......... ..	32	1.8	91	23	1.5	1.7
Without Psychosis..	26	5.8	101	26	1.8	2.7

Of these two groups, the psychotic are older and less well educated, but the Taussig distributions are very like. The non-psychotic surpass the psychotic generally; on Stanford-Binet mean score the difference is possibly, and on digits backwards certainly significant. An item-by-item comparison finds, in all but seven instances (only one of these of any substantial degree), the non-psychotics to be higher. Two of these differences, sentence construction (IX-5) and interpretation of pictures (XII-7) are significant, and three possibly so: counting backwards (VIII-2), designs (X-3) and dissected sentences (XII-1). On sentence memory (X-8) the psychotics are significantly higher[1].

Some time ago the senior author made a study (unpublished) of 23 pairs of feebleminded, one of each pair with, and one without, psychosis. The pairs were matched for sex (11 female; 12 male) and mental age on representative examinations; chronological age was between 16 and 50. Care was taken in each case that the differential diagnosis was clearly justified. Constants for the groups were as follows:

With Psychosis

	Range	Mean and S.E.	S.D. and S.E.
Age	18–45	30.6 ±2.0	9.6 ±1.1
Ed	2–8	5.9 ±0.1	1.8 ±0.3
St-B	62-132	101.8 ±3.9	18.6 ±2.7
Voc	0 40	27.1 ±1.8	8.0 ±1.2
DF	3 7	5.1 ±0.2	0.9 ±0.1
DB	2-4	3.0 ±0.2	0.8 ±0.1

Without Psychosis

	Range	Mean and S.E.	S.D. and S.E.
Age	17-50	26.0 ±1.9	9.3 ±1.1
Ed	3–8	5.9 ±0.4	1.1 ±0.2
St-B	64-139	102.7 ±3.8	18.1 ±2.7
Voc	2–46	26.1 ±2.5	11.7 ±1.8
DF	3–6	5.0 ±0.2	1.0 ±0.1
DB	2–5	3.2 ±0.2	1.0 ±0.1

*In five instances (acute alcoholic psychosis, catatonic dementia praecox, psychopathic personality with psychosis, paranoid condition, and psychoneurosis) the psychopathic group surpassed the normal on sentence memory items, but the difference was usually not even of possible significance. The test, as given in the Stanford, is probably not sufficiently finely graded.

Chi-square analysis of Stanford-Binet items showed no significant differences and only two possibly significant ones: sentence construction (IX-5) and dissected sentences (XII-4), both requiring sustained associative thinking. In both of these the non-psychotic were higher.

In the group reported in the present study, more differences were found on individual items, but the difference in means for the two groups on Stanford-Binet score is too small to justify offering this as explanation. Psychosis apparently has a depressing effect on performance. This seems to be of long standing since there is already some indication of poorer performance in the lower school level achieved.

Chipman (1935) in a study of 135 mental defectives at the Fernald State School found that "groups of individuals diagnosed mentally defective with psychosis" show a tendency to use a larger number of words superior to their mental rating than do mental defectives in whom no question of psychosis has been raised. This finding is consistent with the results reported here.

PARANOID DEMENTIA PRAECOX AND PARANOID CONDITION

	Means					
	Age	Ed	St-B Score	Voc	DF	DB
Paranoid Dementia Praecox......	34	8.5	155	56	6.1	4.5
Paranoid Condition............	40	9.1	165	59	6.0	4.9

The dementia praecox group is significantly younger with somewhat less education, probably a result of the earlier appearance of the psychosis. The Taussig distributions vary, particularly in classes II and III in which the percents are roughly reversed.

Except in the case of digits forwards, the better preservation of the paranoid condition group is reflected in the mean results which are somewhat higher throughout. None of the differences approaches significance, however. The item analysis reveals no surely significant difference, and only one possibly so, that for absurdities (X-2), on which the paranoid condition is higher.

PSYCHOPATHIC PERSONALITY WITHOUT PSYCHOSIS AND PSYCHONEUROSIS

	Means					
	Age	Ed	St-B Score	Voc	DF	DB
Psychopathic Pers. without Psychosis.............	25	7.8	156	49	6.3	4.7
Psychoneurosis.................	28	9.4	169	54	6.5	5.2

These groups are very like in age, although the psychoneurotics are better educated. Taussig distributions are quite dissimilar but it should

be noted that only 62% of the psychopathic group and 69% of the psychoneurotic could be rated. In all mean test results the latter are higher, thought none of the differences approaches significance. Throughout the items, the psychoneurotic group performance is more often the better, and in two cases significantly so: interpretation of pictures (XII-7) and the clock test (XIV-6), both involving associative thinking.

CATATONIC DEMENTIA PRAECOX AND MANIC-DEPRESSIVE

	Means					
	Age	Ed	St-B Score	Voc	DF	DB
Catatonic Dementia Praecox.....	25	9.9	165	57	6.5	4.8
Manic-Depressive...............	35	8.8	166	59	6.7	4.9

Because of the interesting clinical similarities between these two groups, it was thought worthwhile to make a comparison, and the results are presented herewith. In view of the heterogeneity of the dementia praecox groups as a whole, no comparison between total dementia-praecox and manic-depressive groups has been made*.

The manic-depressive group, although also heterogenous, as previously stated, includes only hypo-manic and hypo-depressed patients, the extremes of each falling in the non-representative classification. This is undesirable but unavoidable in our data.

The catatonic group is significantly younger and slightly, but not significantly, better educated, probably an extension of the age difference. Taussig distributions show some differences, but the groups are small and these are not significant.

In both distributions and means the test results are strikingly close, and no significant differences were found anywhere. Psychometric results are thus in accord with the clinical ones.

SUMMARY

Except at the level of the feebleminded, psychosis when it has any specific effect seems particularly to disturb conceptual thinking. In the case of the feebleminded the effect seems more generalized, but some-

*There have been several studies, in which comparisons between manic depressive and mixed dementia praecox groups have been made. In general, these studies have agreed in finding few or no marked differences between these two groups, although the Kendig-Richmond (1940) study reported that the manic-depressives were 11 months higher on median Stanford MA. Some comments should be made on a recent extensive study of this sort, that of Piotrowski (1937). Although he found that "the difference between the manic and depressed states of the manic-depressive psychosis and among the four subgroups of schizophrenia, are larger and more significant than the differences between the two catogories as wholes" he makes some intercomparisons, and then combines all of these groups, along with a scattering of epileptics, general paretics, and others, in a total psychotic group. Comparisons are then made between this group and a group of non-psychotics, described only as having been examined at the Psychiatric Institute or the Vanderbilt Clinic—presumably a group similar to our without-psychosis group (about whose "normality" a question could be raised). These data include also children, the total groups being subdivided by MA levels. From this rather heterogeneous material he constructs typical Stanford-Binet profiles of psychotics and non-psychotics, which he proposes as an aid to their differentiation. Although it is possible that this can be done, the question may be raised as to whether the individual items of the Stanford have sufficient range for such a use or whether such a key can be applied to any particular type of psychosis.

what more on associative thinking*. In the other comparisons, too, the little difference which exists is in the thought items.

Comparisons among Organic Groups, and between an Organic and a Functional Group

GENERAL PARESIS AND CHRONIC ALCOHOLISM WITH PSYCHOSIS

	Age	Ed	Means St-B Score	Voc	DF	DB
General Paresis.................	41	8.6	132	47	5.5	3.7
Chronic Alcoholism with Psychosis................	44	6.9	146	50	5.8	4.1

The groups are similar in age, but the alcoholics are notably less well-educated and in the Taussig distributions, percentages in classes II and III are roughly reversed, *i.e.*, among the paretics are relatively more semi-professional or business and relatively fewer skilled laborers than among the alcoholics. Probably this is because there are no women among the alcoholics, although they comprise approximately one third of the paretic group; women fall for the most part into groups II and IV. A reason for the difference in educational level is not at once manifest, but it is possibly due to the fact that the person who becomes an alcoholic is more likely to have an early personality defect than the person developing paresis—one is the result of endogenous factors which probably develop early while the other results largely from exogenous factors. In spite of this difference in education, the alcoholics are higher in all averages than are the paretics, although none of these differences is significant. On the item analysis, the alcoholics are also generally higher. Two differences—both in conceptual thinking—are significant, similarities (XII-8) and induction (XIV-2); two—involving immediate learning—are possibly so, 4 digits backwards (IX-4) and 6 digits forwards (X-7).

Keeping in mind the fact that the alcoholic group may have been a poorer group to start with, it would appear that the disturbance due to paresis is considerably more profound than that due to the type of psychosis associated with chronic alcoholism.

*This may, however, be due to the lesser frequency of conceptual items at the level at which the feebleminded pass.

GENERAL PARESIS AND FEEBLEMINDEDNESS WITH PSYCHOSIS

	Age	Ed	Means St-B Score	Voc	DF	DB
General Paresis	41	8.6	132	47	5.5	3.7
Feeblemindedness with Psychosis	32	1.8	91	23	1.5	1.7

The data for these show two completely dissimilar groups. The feebleminded are younger, much less well-educated, and with a few exceptions rated only in Taussig groups III to V. They are significantly surpassed by the general paresis on all means and on a majority of the items between VI and XVI years. The latter are so generalized that analysis is impossible. It is obvious that a group of paretics from whom representative results are obtainable do not sink to the intellectual level of the feebleminded. This holds even in a non-representative group of paretics. A comparison of the non-representative group of paretics (page 382) with this group of feebleminded still results in significantly higher means in the paretic group.

The only way to obtain some idea of the profounder effects of the paretic process is to resort to a matching procedure. This, of course, necessitates taking the lower range of the paretic group. In a study by the junior author (unpublished) in which 16 paretics were individually matched for sex and Binet score with 16 feebleminded with psychosis, it was found that the profiles of these groups were quite different. The paretics were consistently better on old learned items, both vocabulary and other types, whereas the feebleminded were consistently better on items involving immediately learned material and to some extent conceptual thinking.

GENERAL PARESIS AND FEEBLEMINDEDNESS WITHOUT PSYCHOSIS

	Age	Ed	Means St-B Score	Voc	DF	DB
General Paresis	41	8.6	132	47	5.5	3.7
Feeblemindedness without Psychosis	26	5.8	104	26	4.8	2.7

The picture here is very similar to the previous one except that the differences are not so sharply defined because of the relatively superior quality of the non-psychotic group. Since the significant item differences are reduced in number it is possible to consider their distributions. It appears that the superiority of the general paresis group comes out

predominantly in vocabulary with a scattering in the classifications of the thinking category. The relatively greater effect of the paretic process on immediate learning is brought out by both comparisons (FIGURE 8).

GENERAL PARESIS AND HEBEPHRENIC DEMENTIA PRAECOX

	Age	Ed	Means St-B Score	Voc	DF	DB
General Paresis	41	8.6	132	47	5.5	3.7
Hebephrenic Dementia Praecox	29	8.5	129	42	5.5	4.3

A comparison of an organic and of a functional disorder is of interest, and for this purpose the paretic and hebephrenic groups were selected, particularly since they were groups which seemed profoundly affected by their respective psychoses. As would be expected, the hebephrenic are considerably younger, but educational level is the same, and occupational distributions are very like.

Stanford-Binet means differ by only 3 months; vocabulary score by only 5.4 words; digits forwards means are the same in the two groups; on digits backwards the paretics for the first time fall below the hebephrenics but the difference is not significant. On item analysis only one difference is significant: difference between abstract words (XII-2) (see FIGURE 8).

We can only conclude that the effect on Stanford-Binet performance of these two psychoses, one organic and one functional in origin, is not determinably different in any meaningful way.

SUMMARY

The outstanding point in this series of comparisons appears to be that the paretic process has a much more profound effect on intellectual functioning than does the alcoholic process, but that this effect is not of such a degree as to bring the paretic down to the level of the feebleminded—psychotic or not. Various lines of evidence point to the fact that in the paretic the old learning is least and new learning most profoundly affected.

As between the effects in an organic condition—paresis—and a presumably profoundly disturbed functional condition—hebephrenic—there is little to distinguish them in Stanford-Binet performance.

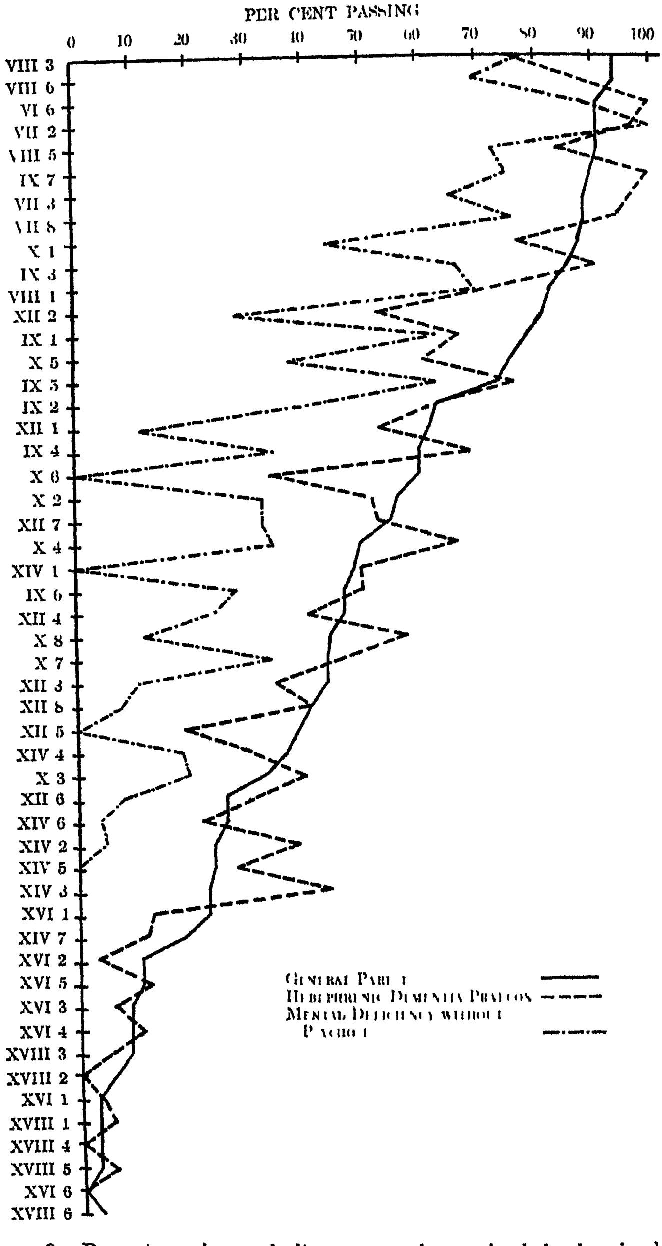

FIGURE 8. Percent passing each item: general paresis, hebephrenic dementia praecox, and feeblemindedness without psychosis. Representative groups. The two psychotic groups are quite similar, and only once (VII-2) fall as low as the feebleminded. The items are arranged in order of difficulty for the paretics.

Comparisons of Types of Dementia Praecox

TABLE 20 assembles the data for the comparisons between and among the various types of dementia praecox. It should be noted that the mean ages vary from 21.8 for catatonic to 34.1 for the paranoid and that some of these differences are of some degree of significance. These result in large part from the varying nature of the disease process and the stage at which hospitalization becomes necessary. The groups have from 8.4 to 9.9 years of education, none of the differences being significant. The Taussig distributions are rather different and can to some extent be ascribed to age differences. There is no describable trend.

The relative ranking of the groups in the various mean performances is interesting. The catatonic are always in first or second place, the hebephrenic and unclassified always in fourth and fifth. On digits forwards and backwards, the simple are first and they are second in total Stanford-Binet score. The paranoid are second in vocabulary and third everywhere else. In general, only the differences between the highest and the two lowest are significant. The Stanford-Binet score means (TABLE 32) range from 139.4 (hebephrenic) to 164.8 (catatonic); the catatonic surpass the hebephrenic and the unclassified significantly, and the hebephrenic-paranoid difference is possibly significant. On Stanford-Binet vocabulary (TABLE 33), the means range from 42.0 (hebephrenic) to 57.0 (catatonic); the catatonic and paranoid are significantly, and the simple possibly significantly, better than the hebephrenic. The means on digits forwards (TABLE 34) range from 5.5 (hebephrenic) to 6.6 (simple). The simple, catatonic and paranoid groups and possibly the unclassified are all significantly better than the hebephrenic. On digits backwards (TABLE 35) the range is from 4.1 (hebephrenic) to 5.2 (simple). The simple are significantly better than both the hebephrenic and unclassified groups and possibly better than the paranoid.

Item differences are summarized in TABLE 21 and FIGURE 9. The catatonics are not surpassed by any group on any item; their tally over the paranoids is 1½ (problems of fact, absurdities); their tally over the simple is 1 (memory for designs); over the unclassified 7½ and over the hebephrenic 21½.

The paranoid tally 1½ over the simple (memory for designs, 6 digits backwards); 4½ over the unclassified, and 16½ over the hebephrenic.

The simple tally ½ over the paranoid (enclosed boxes); 1 over the unclassified (problems of fact and 7 digits forwards); and 10½ over the hebephrenic.

The unclassified tally 2 over the hebephrenics (similarities, rhymes, fables at XII); and the hebephrenic 1 over the unclassified (bowknot).

TABLE 20

DEMENTIA PRAECOX SUB-GROUPS:
DIFFERENCES BETWEEN TYPES AND SIGNIFICANCE OF THE DIFFERENCES

Age — P Values*

Differences	P	H	C	S	U
P		<.02	<.02		<.02
H	− 5.0		.05>P>.02		
C	− 9.3	− 4.3		5.0>P>.02	
S	− 3.6	+ 1.4	+ 5.7		
U	− 6.0	− 1.0	+ 3.3	− 2.4	

Education — P Values

Differences	P	H	C	S	U
P			All greater than .05		
H	0				
C	+ 1.4	+ 1.4			
S	+ 0.5	+ 0.5	−0.9		
U	− 0.1	− 0.1	−1.5	−0.6	

Stanford-Binet Score

Differences	P	H	C	S	U
P		.05>P> 02			
H	−15.4		<.02		
C	+10.0	+25.4			<.02
S	+ 0.8	+16.2	− 9.9		
U	−10.8	+ 4.6	−20.8	−11.6	

Vocabulary

Differences	P	H	C	S	U
P		< .02			
H	−14.1		<.02	.05>P>.02	
C	+ 0.9	+15.0			
S	− 3.0	+11.1	−3.9		
U	− 6.0	+ 8.1	−6.9	−3.0	

Digits Forwards

Differences	P	H	C	S	U
P		<.02			
H	− 0.6		<.02	<.02	.05>P>.02
C	− 0.4	+ 1.0			
S	+ 0.5	− 1.1	+ 0.1		
U	− 0.1	− 0.5	− 0.5	− 0.6	

Digits Backwards

Differences	P	H	C	S	U
P				.05>P>.02	
H	− 0.2			<.02	
C	+ 0.3	+ 0.5			
S	+ 0.7	+ 0.9	+0.4		>.02
U	− 0.4	− 0.2	−0.7	−1.1	

*All P values not recorded are >.05.

It is usually the case, where there are several differences for one item, that a number of the other groups surpass the hebephrenic and occasionally also the unclassified. This is not always true, however, and on the item with the largest tally, *i.e.*, memory for designs (X-3), the situation is that both paranoid and catatonic groups are significantly better than all of the others.

Of the items with tallies of 3½ and 3, the differences seem to lie mostly in the conceptual and sustained associative thinking classifications. The striking differences come out finally in the hebephrenic group which show inferiority on these items in comparison with the catatonic, paranoid and simple groups, especially the first.

As in the psychotic-normal comparisons made by them, Kendig and Richmond compared percentages of their various dementia praecox types failing each item, and apparently took a difference of 5 per cent or over as a valid one.* They found the paranoid to be "excelled" on 14 tests by the hebephrenic, on 11 by the catatonic, and on 10 by the simple, but the significance of any of these is not clear. They also found the simple frequently superior to the other three groups. Their comment on this is of considerable interest (p. 60), "In general, the success of the simple praecox is scattered throughout the scale, but the recurrence of the digit tests in the list, together with syllables at 16 and designs at 10, suggests that their simple memory processes may be the best preserved." Our simple group had the highest means for both digits forwards and digits backwards.

It is not possible to compare our findings on the separate groups with those of Kendig and Richmond in great detail, because of the difference in approach. The situation is further obscured by their inclusion in the type comparisons of the colored patients, in unstated numbers in each particular group. Race differences on each item are considered by them for the total groups only. The further analysis of transpositions in order of difficulty of tests from one age level to another which they made in great detail for all of their groups, including their subgroups of dementia praecox, seems to us of questionable value. The Stanford-Binet when used with adults does not differ essentially from such tests as the Otis S. A. (although we consider it superior to the Otis in almost every way) in respect to the exact location of items in the series. Differences in performance of any two groups on any given item may be of very

*Comparison on this basis is of course not of statistical significance. It is possible to compare percents by the critical ratio technique but this is only admissible around the 50 percent point; this type of comparison is not valid at higher or lower levels. The chi-square technique, however, does give accurate information at all levels.

great importance, but the serial location of the item as, *e.g.*, 27 or 32, is of very little importance.

The contents of this section confirm our earlier remarks about the fallacies inherent in the practice of merging dementia praecox groups. In summarizing the results the remarks about the probable selection of these cases from their total diagnostic groups must be recalled, *i.e.*, that it is likely that the catatonics here reported are relatively more superior

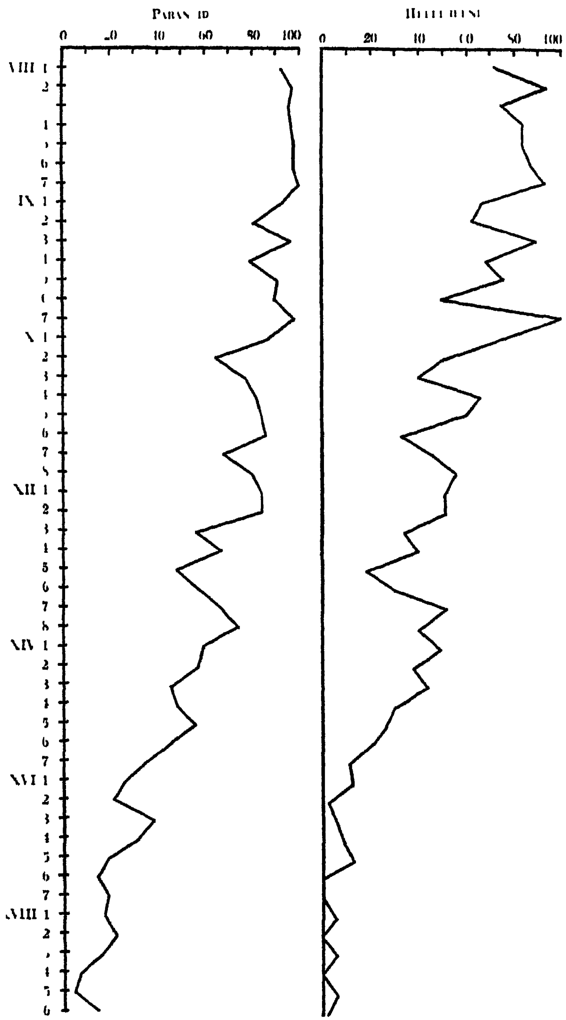

FIGURE 9. Percent passing each item: all types of dementia praecox. Representative groups. Items arranged in order of scale location.

in performance to the total catatonic group than is true of the representatives of the other types. The hebephrenics are certainly the most clearly set-off of any of the groups by reason of their consistent inferiority to all of the others, though this is slight in comparison with the unclassified. The general superiority of the catatonic and paranoid to the other groups is almost equally apparent. The catatonic group somewhat surpasses the paranoid generally and it is of interest that the items on

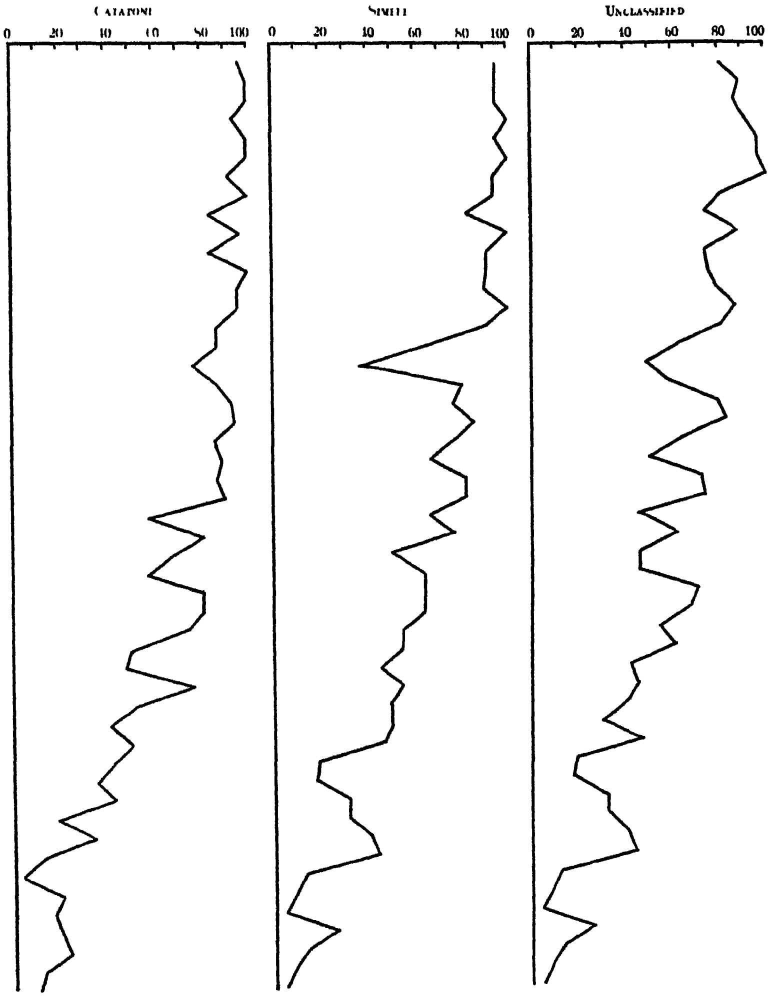

FIGURE 9 (Continued)

TABLE 21

DEMENTIA PRAECOX SUB-GROUPS

ITEM ANALYSIS

	Items	.05>P>.02	P=.02 or less	Tally
VII–4	Bowknot		C>U; P>U; H>U	3 LRO
VIII–1	Ball and field		C>H; P>H	2
2	20–1			0
3	Comprehension		C>H; P>H; S>H	3 TAS
4	Similarities			0
5	Differences			0
6	Vocabulary			0
IX–1	Date		C>H; P>H	2
2	Weights		P>H	1
3	Change			0
4	4DB			0
5	Sentences	P>U	C>U; C>H; S>H	3½ TAS
6	Rhymes	U>H	C>H; P>H; S>H	3½ TAS
X–1	Vocabulary			0
2	Absurdities	C>P; C>U	C>H	2 TC
3	Designs		C>S; C>U; C>H; P>S; P>U; P>H	6 LI
4	Reading	C>U	P>U	1½
5	Comprehension		C>H; P>H	2
6	Free assoc.		C>H	1
7	6DF	S>H	C>H	1½
8	22 Syllables		C>U; P>U	2
XII–1	Vocabulary		C>H; P>H	2
2	Abstract words		C>H; P>H	2
3	Ball and field	S>H		½
4	Dissected sent.	P>H	C>H; S>H	2½ TAS
5	Fables	U>H	C>H; P>H; S>H	3½ TC
6	5DB	C>H	P>H; S>H	2½ LI
7	Pictures	C>H		½
8	Similarities		C>H; P>H; U>H	3 TC
XIV–1	Vocabulary			0
2	Induction			0
3	Pres. and king			0
4	Problems	S>U	C>P; C>U; C>H	3½ TC
5	Arith. reas.		P>H	1
6	Clock	P>H; S>H		1
7	7DF	S>U	C>U; C>H; S>H	3½ LI
XVI–1	Vocabulary	C>U		½
2	Fables	C>U	C>H	1½
3	Abs. terms	S>H	C>H; P>H	2½ TC
4	Encl. boxes	P>H		½
5	6DB	S>P; S>H		1
6	Code		S>H	1
7	28 syllables			0
XVIII–1	Vocabulary			0
2	Paper cutting		P>H	1
3	8DF			0
4	Thought passage		C>H	1
5	7DB			0
6	Ingenuity			0

which the catatonics are superior are conceptual thinking problems.

In addition to the above the inter-comparison of correlation coefficients among the types may also be considered. (Correlations for these types are given with the others in TABLE 19 where they are compared with the normal.) There appear no differences with a P of .02 or less*. There were, however, four differences with a P between .05 and .02. The CA/MA correlations run from −.28 for the simple to +.31 for the catatonic. The difference between these two extremes is of possible significance as is also that between catatonic and unclassified. The smaller age range in the catatonics is probably a factor here. The MA/education correlations range from +.47 for the unclassified to +.72 for the hebephrenic. The CA/vocabulary correlations, except for the catatonic, are reasonably consistent, ranging from −.11 for the unclassified to +.13 for the paranoid. The catatonic correlation is +.44; the mean catatonic age differs from the paranoid with a P of .02 and from the hebephrenic and simple with a P between. 05 and .02. The catatonics, more than the others are at ages in which vocabulary performance is apparently still increasing. The vocabulary/MA correlations range from +.80 for the simple to +.92 for the paranoid, and the difference between these extremes is of possible significance. The correlations for vocabulary and digits forwards range from +.25 for the simple to +.53 for the unclassified, and for vocabulary/digits backwards, they range from +.44 for the catatonic to +.63 for the unclassified.

Below are given the ranks of each group, numbered from lowest to highest for three sets of correlations:

	Voc and MA	Voc and DF	Voc and DB
DPP............	5	4	2
DPH............	2	2	4
DPC............	3	3	1
DPS	1	1	3
DPU............	4	5	5

Although the vocabulary/MA correlations are throughout much higher than the vocabulary/digits forwards, the relative position of the groups are almost identical. This does not hold, however, for the vocabulary, digits backwards correlations.

THE RELATIVE EFFECTS OF DISORDER AND OF NON-REPRESENTATIVENESS ON TEST PERFORMANCE

The material on which this discussion is based has been presented above (pages 378–428), where the separate effects of these two factors on

*Differences computed from z's as before.

test performance were analysed in detail. Here an attempt is made to assess the relative influence of these two factors. Discussion will be limited to the seven groups: general paresis, paranoid, hebephrenic, catatonic and unclassified dementia praecox, manic-depressive, and psychopathic personality without psychosis. We may examine the mean performances for these groups in two ways in terms of differences between normal and representative and between representative and non-representative groups which showed significance, and in terms of percents.

TABLE 22 brings together the significant differences between the means.

TABLE 22

SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS IN REPRESENTATIVE NORMAL AND REPRESENTATIVE NON-REPRESENTATIVE COMPARISONS

	Representative/Normal		Representative Non-representative	
	.05 > P > .02	P ≤ .02	.05 > P > .02	P ≤ .02
St-B		GP; DPH; DPU		GP; DPP; DPH; DPC
Voc	GP	DPH		
DF		GP; DPP; DPH; DPU; PP+	DPH	DPC, MD
DB		GP; DPH; DPU		DPH

It is immediately apparent that there are more significant differences between normal and representative than between representative and non-representative groups, and that there are some differences in the individual groups in these respects, *e.g.*, significant differences in the catatonic and manic-depressive appear only in the latter and in the unclassified dementia praecox and the psychopathic personality with psychosis only in the former.

TABLE 23 gives a series of percentages. In each instance, the first column gives the representative group mean expressed as a per cent of the normal mean, and the second column gives the non-representative group mean expressed as a percent of the representative mean.

Again it is clear that the catatonic and manic-depressive are adversely affected only by non-representativeness; the paretic and hebephrenic are markedly affected by both the psychosis and non-representativeness.

TABLE 23

REPRESENTATIVE MEANS AS PERCENTS OF THE NORMAL MEANS AND NON-REPRESENTATIVE MEANS AS PERCENTS OF THE REPRESENTATIVE MEANS

	St-B Score		Vocabulary		Digits F		Digits B	
	R/N	nR/R	R/N	nR/R	R/N	nR/R	R/N	nR/R
GP	81	86	87	83	82	96	76	81
DPP	95	88	103	87	91	95	92	93
DPH	79	81	77	71	82	89	88	77
DPC	100	85	105	87	97	91	98	94
DPU	88	92	92	86	90	97	84	110
MD	101	87	108	97	100	85	100	84
PP+	95	89	90	94	93	98	98	96
Aver.	91	87	95	87	91	93	90	91

Comparisons of the results on the individual items are not particularly illuminating but show some trends. A few items receive fairly high tallies in both groups. These are:

	Normal/Rep	Rep/Non-rep
Giving the date (IX-1)	2	2½
Giving rhymes (IX-6)	2	2
Absurdities (X-2)	4	3½
Problems of fact (XIV-4)	3	2½

There are a few items which are discriminative in more of the representative/non-representative comparisons than in the normal/representative comparisons, but the differences are not great, and do not show any definite trend. It is apparent that the trend due to un-representativeness is similar to that found in the differences due to the disorder itself, that is, conceptual thinking seems to be the most affected. The item of giving the date is quite interesting—it is, in fact, a measure of contact with reality, and it is not surprising that both psychosis and representativeness should affect it.

SUMMARY

In effect, then, while differences between normal and representative abnormal groups are greater and more numerous than those between representative and non-representative, the latter are in the same direction and of the same nature as the former.

In any research with abnormals, the problem of the inclusion or exclusion of non-representative results is the first one to be settled, and the answer depends upon the specific purpose. When non-representative results are excluded, the effect of this selection is clear. In comparisons

with normals the number of significant differences and the degree of significance will be lessened, and as a result, some true differences may not show up, but there is greater certainty that differences which do appear are real differences.

THE EFFECT OF MENTAL DISORDER ON INTELLIGENCE

In most of the psychoses and psychopathies, we found deviations from normal intellectual functioning which, however, varied considerably in degree from one type of disorder to another. These deviations were of two sorts: a general lowering of performance and a more marked lowering in some types of tests than in others.

TABLE 24 lists all of the groups arranged in order of mean Stanford-Binet score. Some of these groups are above the normal, many only slightly below. Indeed, the first 12 on the list do not differ significantly from the normal, although the without psychosis group has a P for the difference of between .02 and .05. It should be noted that there is only one non-representative group in this range—the psychoneurotic.

The next mean score is seven months lower, and all of the representative groups left differ significantly from the normal. The non-representative are interspersed among these. The order in which the groups appear is similar for the representative and non-representative subdivisions (ρ is .864) and, with three exceptions, it is generally true that the severer the disorder in its clinical manifestations, the greater is the lowering effect on Stanford-Binet mean score. Manic-depressive and catatonic both have mean scores slightly above normal. The tests on the manic-depressive were all made during comparatively quiescent periods of the psychosis and it has been widely noted that this group is not a "deteriorative" one. The representative catatonic group is believed to be a relatively highly selected one. The other exception is the large group, without psychosis, to which we have already devoted considerable discussion. Its heterogeneity makes any definite generalization impossible; we can only note that it is far from the normal.

Some part of this lowering, both general and specific, may be attributed to difficulties in attention, even with cooperative patients; but a postulated difficulty in attention alone cannot account for the significant and considerable general lowering in the organic paretic and psychotic chronic alcoholic and the non-organic hebephrenic and unclassified dementia praecox groups, nor, if this were all, would we have the marked differences between items.

TABLE 21

MEAN STANFORD-BINET SCORES OF ALL GROUPS
ARRANGED IN RANK ORDER

		St-B Score
R	Psychoneurosis	169.1
R	Manic Depressive	166.4
R	Catatonic Dementia Praecox	164.8
R	Paranoid Condition	164.7
	Normal	163.6
R	Psychopathic Personality s̄ Psychosis	156.4
R	Psychopathic Personality c̄ Psychosis	156.1
R	Simple Dementia Praecox	155.5
R	Chronic Alcoholism s̄ Psychosis	155.2
R	Paranoid Dementia Praecox	154.8
R	Acute Alcoholic Psychosis	154.2
n-R	Psychoneurosis	153.1
R	Without Psychosis	152.7
R	Chronic Alcoholism c̄ Psychosis	145.9
n-R	Manic Depressive	144.6
R	Unclassified Dementia Praecox	144.0
n-R	Psychopathic Personality s̄ Psychosis	143.8
n-R	Paranoid Condition	143.8
n-R	Catatonic Dementia Praecox	140.1
n-R	Psychopathic Personality c̄ Psychosis	138.8
n-R	Paranoid Dementia Praecox	135.7
n-R	Without Psychosis	133.7
R	General Paresis	132.1
n-R	Acute Alcoholic Psychosis	131.8
n-R	Unclassified Dementia Praecox	131.6
R	Hebephrenic Dementia Praecox	129.4
n-R	Chronic Alcoholism s̄ Psychosis	127.0
n-R	General Paresis	113.4
n-R	Chronic Alcoholism c̄ Psychosis	110.8
n-R	Hebephrenic Dementia Praecox	105.1
R	Feeblemindedness s̄ Psychosis	104.4
n-R	Simple Dementia Praecox	101.7
R	Feeblemindedness c̄ Psychosis	93.8
n-R	Feeblemindedness c̄ Psychosis	92.8
n-R	Feeblemindedness s̄ Psychosis	91.6

Rouvroy's (1936) interpretation is that automatised reactions remain at approximately their former level, while those involving new adjustments are alone affected, but this, while having a considerable element of truth, does not take account of all of the facts.

Dearborn's (1927) analysis of the nature of intellectual regression included these factors: lowering of the power of voluntary attention;

derangement of conceptual association, resulting in inability to make inferences, derangement of perception, development of a sort of mental evasion, capable of modifying the intellectual process in many ways. This analysis is in close accord with much of ours.

It is, however, impossible to get a very clear picture of the situation from an omnibus score; there can be real differences which are not revealed in the total score; nor does total score alone give us any indication as to whether the lowering, even when markedly present, is general and unselective or appears more frequently in certain functions. To investigate this, the items were studied individually, and where possible, as series, *i.e.*, vocabulary, digits forwards, and digits backwards.

Mean vocabulary score in the representative groups (see TABLE 25) varies from 42.0 to 58.8 (the mean for normals is 51.5), being lowest in the groups recognized on other criteria as showing the greatest disturbance in the cognitive sphere. In the representative/non-representative comparisons, mean vocabulary score was in every instance (omitting the feebleminded) lower in the latter, the differences ranging from −2.0 for the manic-depressive to −12.0 for the without psychosis. None of these differences, however, could be considered significant statistically. The use of the vocabulary test as a valid indicator of a patient's original level was discussed above (pages 428–436), where it was shown that there was doubt, particularly in some groups, of the adequacy of the criterion. In all of our groups, including the normal, vocabulary expressed in terms of MA was higher than Stanford-Binet MA, and in many of them the difference was considerable. In two of our groups, general paresis and hebephrenic dementia praecox, vocabulary level was far below the level of previous education; here it is very obviously not an adequate measure of previous level, even though it may be a better one than Stanford-Binet MA. Thus some correction must apparently be made for the appearance of a discrepancy between vocabulary and other performances in normal groups and for the differential effects of age on vocabulary and other performances. Even so, a residue of difference remains which appears to be associated with psychotic process. The differences between mean MA and the mean equivalent of vocabulary MA are in general larger in the non-representative than in the representative groups, ranging from −17 to −34 as against −4 to −27 for the representative groups.

One of our most striking and consistent results has been the effect of psychosis on the repetition of digits forwards (TABLE 26). We found that none of the groups has a mean above the normal group; that of 15 representative groups, 8 had means significantly lower and one a mean

TABLE 25

MEAN VOCABULARY SCORES OF ALL GROUPS
ARRANGED IN RANK ORDER

Group		Vocabulary Score
R	Paranoid Condition	58.8
R	Manic Depressive	58.7
R	Catatonic Dementia Praecox	57.0
n-R	Manic Depressive	56.7
R	Paranoid Dementia Praecox	56.1
R	Acute Alcoholic Psychosis	54.9
n-R	Psychoneurosis	54.8
R	Normal	54.5
R	Chronic Alcoholism s̄ Psychosis	54.5
R	Psychoneurosis	53.7
R	Simple Dementia Praecox	53.1
n-R	Paranoid Condition	52.1
R	Dementia Praecox	52.1
R	Unclassified Dementia Praecox	50.1
R	Chronic Alcoholism c̄ Psychosis	49.9
n-R	Catatonic Dementia Praecox	49.5
R	Psychopathic Personality s̄ Psychosis	49.2
R	Psychopathic Personality c̄ Psychosis	48.9
n-R	Paranoid Dementia Praecox	48.7
R	Without Psychosis	48.0
R	General Paresis	47.4
n-R	Psychopathic Personality c̄ Psychosis	45.9
n-R	Unclassified Dementia Praecox	43.3
R	Hebephrenic Dementia Praecox	42.0
n-R	Psychopathic Personality s̄ Psychosis	40.0
n-R	Acute Alcoholic Psychosis	39.7
n-R	General Paresis	39.1
n-R	Chronic Alcoholism s̄ Psychosis	38.0
n-R	Without Psychosis	36.0
n-R	Chronic Alcoholism c̄ Psychosis	34.8
n-R	Hebephrenic Dementia Praecox	31.2
n-R	Simple Dementia Praecox	29.0
R	Feeblemindedness s̄ Psychosis	26.0
R	Feeblemindedness c̄ Psychosis	22.7
n-R	Feeblemindedness c̄ Psychosis	22.1
n-R	Feeblemindedness s̄ Psychosis	20.7

of possibly lower significance than the normal. Of the seven representative/non-representative comparisons (excluding feebleminded and without psychosis) two of the non-representative means were of definitely, and one of possibly, lower significance than the normal. In general,

TABLE 26

MEAN DIGITS FORWARDS SCORE OF ALL GROUPS ARRANGED IN RANK ORDER

	Group	DF Score
R	Manic Depressive	6.7
R	Normal	6.7
R	Simple Dementia Praecox	6.6
R	Psychoneurosis	6.5
R	Catatonic Dementia Praecox	6.5
R	Chronic Alcoholism s̄ Psychosis	6.3
R	Psychopathic Personality s̄ Psychosis	6.3
R	Psychopathic Personality c̄ Psychosis	6.2
n-R	Psychopathic Personality c̄ Psychosis	6.1
n-R	Without Psychosis	6.1
R	Paranoid Dementia Praecox	6.1
R	Dementia Praecox	6.1
R	Acute Alcoholic Psychosis	6.0
R	Unclassified Dementia Praecox	6.0
R	Paranoid Condition	6.0
R	Without Psychosis	6.0
n-R	Catatonic Dementia Praecox	5.9
R	Chronic Alcoholism c̄ Psychosis	5.8
n-R	Paranoid Dementia Praecox	5.8
n-R	Unclassified Dementia Praecox	5.8
n-R	Paranoid Condition	5.8
n-R	Acute Alcoholic Psychosis	5.7
n-R	Manic Depressive	5.7
n-R	Psychoneurosis	5.7
n-R	Simple Dementia Praecox	5.6
R	General Paresis	5.5
n-R	Chronic Alcoholism s̄ Psychosis	5.5
R	Hebephrenic Dementia Praecox	5.5
n-R	Psychopathic Personality s̄ Psychosis	5.5
n-R	General Paresis	5.3
n-R	Hebephrenic Dementia Praecox	4.9
n-R	Chronic Alcoholism c̄ Psychosis	4.8
R	Feeblemindedness s̄ Psychosis	4.8
n-R	Feeblemindedness c̄ Psychosis	4.6
R	Feeblemindedness c̄ Psychosis	4.5
n-R	Feeblemindedness s̄ Psychosis	4.3

the severer the clinical manifestations of the disorder the more marked the impairment here. We do not find the same situation with sentence memory, but this test is a much grosser one, many of the items are alternates and therefore the groups available are smaller. It is impossible to tell from our evidence whether one is here dealing with a true

memory defect, or whether these lower means reflect rather a lowering of the span of attention which may be particularly marked with material that is essentially non-meaningful and unpatterned. If it is, in fact, basically a defect in attention, then this must be taken into account in the interpretation of results on other tests, although meaningfulness of the material may alter the span considerably.

The situation with regard to digits backwards is quite different (TABLE 27). This task is far from simple rote memory, but is much more closely related to general intellectual level, as other authors have noted. It is of particular interest that the four representative groups differing significantly from the normal on this are the same four which alone showed a significant difference on mean Stanford-Binet score, namely general paresis, chronic alcoholism with psychosis and hebephrenic and unclassified dementia praecox. (The without psychosis had a possibly significant difference in mean Stanford-Binet and an insignificant difference in digits backwards.) On the representative/non-representative comparisons, only the hebephrenic dementia praecox of the four non-representative groups significantly lower on Stanford-Binet than the representative, was significantly lower on digits backwards also.

An analysis of the types of items (TABLE 28) indicates that psychosis seems to affect mostly conceptual thinking and immediate learning, and least old learning items. In the former 8 to 10 of the 15 groups are affected whereas in the latter only 3 of the 15 groups are. From this and from the fact that there seems to be a distinct stepwise phenomenon of increasing disturbance in groups disturbed in many types, it seems legitimate to postulate a certain order of selectivity in the degree to which types of tests are affected. Essentially it is this: (1) conceptual thinking; (2) immediate learning; (3) sustained associative thinking, immediate associative thinking, vocabulary; (4) old learning.

Insofar as psychosis is concerned the hebephrenic dementia praecox and general paresis are affected in all functions. These together with unclassified dementia praecox are the most affected groups. On the other hand the acute alcoholic, manic-depressive, psychopathic personality without psychosis and psychoneurosis groups are not significantly affected in any of the types of items.

Variability of performance, as indicated by standard deviations, is greater in the psychotic than in the normal groups, and this is particularly true for the dementia praecox groups.

In general, correlations are remarkably consistent and do not deviate greatly from those found in the normal group. The vocabulary/MA correlation for the paranoid dementia praecox group is significantly

TABLE 27

MEAN DIGITS BACKWARDS SCORE OF ALL GROUPS ARRANGED IN RANK ORDER

	Group	DB Score
R	Simple Dementia Praecox	5.2
R	Psychoneurosis	5.2
R	Manic Depressive	4.9
R	Paranoid Condition	4.9
R	Normal	4.9
R	Catatonic Dementia Praecox	4.8
R	Psychopathic Personality c̄ Psychosis	4.8
R	Psychopathic Personality s̄ Psychosis	4.7
n-R	Psychopathic Personality c̄ Psychosis	4.6
n-R	Psychoneurosis	4.6
R	Chronic Alcoholism s̄ Psychosis	4.5
R	Acute Alcoholic Psychosis	4.5
R	Paranoid Dementia Praecox	4.5
n-R	Catatonic Dementia Praecox	4.5
n-R	Unclassified Dementia Praecox	4.5
R	Dementia Praecox	4.5
R	Without Psychosis	4.5
n-R	Paranoid Condition	4.4
R	Hebephrenic Dementia Praecox	4.3
n-R	Psychopathic Personality s̄ Psychosis	4.3
n-R	Paranoid Dementia Praecox	4.2
R	Chronic Alcoholism c̄ Psychosis	4.1
R	Unclassified Dementia Praecox	4.1
n-R	Manic Depressive	4.1
n-R	Chronic Alcoholism s̄ Psychosis	4.0
n-R	Without Psychosis	4.0
n-R	Acute Alcoholic Psychosis	3.8
R	General Paresis	3.7
n-R	Hebephrenic Dementia Praecox	3.3
n-R	General Paresis	3.0
n-R	Simple Dementia Praecox	3.0
R	Feeblemindedness s̄ Psychosis	2.7
n-R	Feeblemindedness c̄ Psychosis	2.3
n-R	Chronic Alcoholism c̄ Psychosis	2.1
n-R	Feeblemindedness s̄ Psychosis	1.7
R	Feeblemindedness c̄ Psychosis	1.7

higher than the normal. The psychotics definitely tended to higher correlations between vocabulary/digits forwards and vocabulary/digits backwards although none of the differences are significant. The order of the size of the correlations in the former appears random, but in the

TABLE 28

TYPES OF ITEMS AFFECTED IN REPRESENTATIVE GROUPS

	LRO	VOC	TAI	TAS	LI	TC	No. †
General Paresis	†	†	†	†	† †	† †	8
Chronic Alcoholism c̄ Psychosis	0	†	0	†	†	†	4
Chronic Alcoholism s̄ Psychosis	0	0	0	0	0	†	1
Acute Alcoholic Psychosis	0	0	0	0	0	0	0
Paranoid DP	0	†	†	0	†	† †	5
Hebephrenic DP	†	† †	† †	† †	† †	† †	11
Catatonic DP	0	0	0	0	0	†	1
Simple DP	0	0	†	0	†	†	3
Unclassified DP	†	†	†	†	†	† †	7
Manic Depressive	0	0	0	0	0	0	0
Psychopathic Personality c̄ Psychosis	0	0	0	†	0	†	2
Psychopathic Personality s̄ Psychosis	0	0	0	0	0	0	0
Paranoid Condition	0	0	0	0	†	0	1
Psychoneurosis	0	0	0	0	0	0	0
Without Psychosis	0	†	†	†	†	†	5
No. groups with † or † †	3	6	6	6	8	10	
Total No. †	3	7	7	7	10	14	48

0 - None
† = 1 - 40%
† † - 41% above

latter case (vocabulary/digits backwards) there is a tendency for the group with higher mean Stanford-Binet scores to have the lower correlations.

Our material offers no evidence on the permanence of the changes which have appeared. The improvement in mental functioning as well as in the rest of the disease in general paresis under the newer treatments throws the question open again, although it seems to be the case that with patients whose psychosis becomes progressively more severe the levels of cognitive functioning are permanently lowered. Should any effective treatment be developed for the grosser forms we do not know that this apparent deterioration could not be overcome. But to study this point as well as many others, we need a more adequate method than any that is as yet available. There may be a cue, however, in the combined disturbance of MA and vocabulary. We have found both together significantly disturbed only in the paretic and hebephrenic groups. It is possible that when vocabulary becomes disturbed significantly in addition to MA level that we are dealing with a process which with some justification may be considered a deteriorative one.

SUMMARY AND CONCLUSIONS

In a study dealing with so many variables in so many different groups, it is difficult to keep from becoming lost in a morass of details, especially as many of the observed facts seem at first glance to be isolated ones, not fitting into any general pattern. On further examination, however, certain definite findings appear which can be welded into fairly coherent wholes, and certain trends become clearly apparent. We will sum these up under several headings, viz., representativeness, relationship between intelligence and mental disorder, the effect of mental disorder on intelligence and changes in the individual groups.

Representativeness

In psychometrics, as in experimental psychological work, we have shown that the presence or absence of cooperativeness has considerable effect on the results in psychotic groups. In general, the effect of representativeness is rather less than that of psychosis, but it is of the same nature. The situation is not the same in all of the diagnostic groups. In the groups severely affected by psychosis, non-representativeness has a fairly large additional effect. There are several groups which are little affected by psychosis, but in which some effect of non-representativeness can be demonstrated, namely, the manic-depressive and the catatonic dementia praecox.

It was clear that the judgment of representativeness or non-representativeness was more difficult to make in some groups than in others. In the groups feeblemindedness with psychosis and without psychosis the criteria as hitherto applied seemed not to differentiate accurately and they also proved not entirely adequate in the unclassified dementia praecox group. In the case of the feebleminded group it seemed evident that the difficulty arose from the specific situation unsatisfactory responsiveness due to stupidity and unsatisfactory responsiveness due to psychosis are particularly difficult to differentiate. In the without psychosis group, the difficulty seemed to be largely in the samples, and in the unclassified dementia praecox group both difficulties seemed to play a part.

As a result of this study, we felt that our disordered-normal comparisons would be of greater value if we excluded the non-representative in the disordered groups. The effect of this selection must be kept in mind in consideration of our further results. Because of it, the degree of significance and the number of significant differences will be lessened, and the net result is that while some true differences may not appear, we may

be reasonably certain that the differences which do appear are more dependable differences.

The Nature of the Relationship between Intelligence and Mental Disorder

We have shown that, in general, the severer the psychotic condition, the farther from the normal is the psychometric performance. Such a difference can be interpreted in two ways: (1) As demonstrating the effect of psychosis on cognitive function, or (2) As demonstrating the selective effect of intelligence on psychosis, *i.e.*, that certain types of psychoses appear at certain levels of intelligence rather than at others*.

Ordinarily the latter theory is put forward, not with respect to all psychoses, but rather to particular ones, *e.g.*, Tendler's conclusion that an initial low level conduces to neuroticism; Duncan's belief that feeble-mindedness is an etiological factor in manic-depressive insanity; and the widely held opinion that paranoia attacks chiefly those of superior intellectual level. With the evidence supplied by Tendler and Duncan we have dealt at some length; we do not find it impressive.

The implications of this point of view have not been very carefully examined by its adherents. The fact of the existence of differences in intelligence between normal and abnormal groups does not in itself offer any clues as to the nature of the relationship; this must be inferred on other criteria and in accord with psychiatric as well as with psychologic evidence. Now, if it were the case that the level of pre-psychotic intelligence in the individual determined the nature of the psychosis to which he might be subject, then the generally accepted concept of a psychosis as primarily a disorder of the personality, particularly of its affective aspects, must be in error. For such a drastic revision of basic psychiatric theory there is no valid evidence. On the other hand, the interpretation of these differences as the effects, in the cognitive field, of the disorder of the psychologic personality is in complete accord with psychiatric knowledge, and in no way opposed by the psychologic evidence.

The differences in mean test performances found by many experimenters (although not always in the same direction nor to the same extent) are not all of the evidence available. It is enlightening to compare the distributions. This comparison shows considerable overlapping of both ranges and standard deviations, even when the means differ significantly. This seems to us a potent argument against the inter-

*There is, of course, a third possibility, that neither is responsible, but that they are associated results of some other cause. In this instance, we believe the relationship can be explained without recourse to an unknown factor.

pretation that original level of intelligence may determine in any substantial part the type of psychosis.

These data together with the material presented earlier based on educational level seem reasonable evidence that there are very few, if any, disorders in which the type of psychosis developed is dependent to any extent on intellectual level.

Some further comment should be made about the commonly held position that paranoid conditions of one kind or another occur more frequently in the upper levels of intelligence. It is true that our paranoid condition and paranoid dementia praecox groups are well up generally as far as means go, but again the dispersal is extensive, and if this disease has originally attacked only the more intelligent then the deterioration in some of these cases must be much greater than the clinical picture would lead one to infer. (It is generally accepted that these types deteriorate rather slowly.) A pure paranoia rarely occurs, but the trend towards broad distribution appears in many of the other groups, in varying degrees. We suspect that the typical paranoid verbosity has been a confusing factor, and from the extent and press of verbal activity has been deduced a level of verbal intelligence, even of general intelligence, which is not actually present.

The Effect of Mental Disorder on Intelligence

In the presence of any psychotic or psychopathic process, certain changes in mental functioning may occur. These are in the direction of a lowering of the level of functioning and are both general and specific in nature. There is no doubt but that some part of this lowering may be attributed to difficulties in attention, and to what extent this basic function is affected we cannot say. It is clear, however, that it is not the only function that is affected.

Our analysis has shown that in the severely disordered mind, all types of intellectual activity are interfered with, some more and some less than others. Vocabulary is less affected in general than the other tests in all groups. Vocabulary expressed in terms of MA was higher than Stanford-Binet MA, and in many of the groups the difference was considerable; the difference was generally larger in the non-representative groups. To that extent, it is probably a better indicator of general level than is Stanford-Binet MA, but that it is not an adequate one is shown by the fact that in two groups it was far below the level of previous education.

One of our most striking results was the consistency with which the repetition of digits forwards was affected by psychosis. Of our 15 representative groups, 8 had means significantly and 1 a mean possibly

significantly lower than the normal mean. The non-representative are generally lower than the representative. In general, the severer the clinical manifestations of the disorder the more marked the impairment in this test. We do not know how much of this disturbance is purely a memory disturbance and how much is due to disturbance of the span of attention. But that such a disturbance is present and to such an extent is a fact of importance in assessing test results in disordered groups. Repetition of digits backwards does not show so much effect. It is a task more closely related to general intellectual functioning than to simple rote memory.

As far as the type of items most affected is concerned, our analysis has shown that those primarily affected are of the conceptual thinking and immediate memory group, and that those least affected are old learning items.

Variability of performance appears to be greater in the psychotic than in the normal group, and this increase in variability is most apparent in the various dementia praecox groups.

The comparison of correlations between different tests for the normal and disordered did not bring out any definite trends.

Although our material has shown clearly that disordered groups do not function as well intellectually as non-disordered groups we cannot speak of this change of function as "deterioration." As yet we know nothing about the irreversibility of this change. It should be noted that in the hebephrenic dementia praecox group, in whom, so far as is known, there is no organic change, the functional disturbance is even greater than it is in the general paresis group.

Changes in the Various Disordered Groups

Although the changes discussed above follow much the same pattern in all of the disordered groups, there are some differences between the various diagnoses. The findings for each group are therefore summed up here.

GENERAL PARESIS

Next to the hebephrenics, the paretics are the most severely affected of any group studied, as shown in mean and item differences from the normal. The paretic's impairment is marked—he falls at about an 11 year mental level—and general, but in addition he shows particularly severe difficulty with immediate memory and conceptual thinking.

The paretic is much more profoundly disturbed in cognitive functioning than the psychotic alcoholic, and this disturbance is very nearly as

extensive as that in the hebephrenic from which it does not differ in any meaningful way. But, profound as this disturbance is, it does not reduce the paretic to the level of the feebleminded, whether psychotic or not. In the latter comparison it is interesting to note that the paretics were consistently *relatively* better on old learned items, and the feebleminded on immediate memory and, to a lesser extent, on conceptual thinking.

THE ALCOHOLICS

Comparisons with normals, and comparisons among the three members of the group bring out few statistically significant differences, but show a consistent trend. The acute and the non-psychotic chronic groups, although generally lower, differ comparatively little from the normal, and from each other on test results; the psychotic chronic alcoholics tend to fall below the two others throughout and are well below the normal. It would seem that psychosis rather than alcoholism, even over long periods, is the factor affecting test performance, and, further, that it is not alcoholism, *per se*, which induces the psychosis.

DEMENTIA PRAECOX

In comparison with the normal, what seems to stand out is the closeness of the catatonic, simple and paranoid groups (in that order) to the normal. Except for a few items on which significant differences are found, there is little to distinguish these groups from the normal. However, the unclassified and especially the hebephrenic distinguish themselves clearly from the normals, the latter, in fact, most of any of the groups studied. The unclassified with a mental level of about 125 months stands third in rank order of difference in items from the normals. These fall largely in the conceptual and associative thinking groups. In means, all but vocabulary are significantly lower. Hebephrenic dementia praecox, showing the greatest difference from normal, show it in all means and in all types of items. The average mental age level is somewhat below 11. Apparently psychosis has the most profound effect on this group.

A careful intercomparison of the various dementia praecox groups indicates that there is no justification for lumping all types into a total dementia praecox group, at least in psychometric research, since the differences among the types are in many instances greater than between the dementia praecoxes and other groups.

In general, the catatonics are the highest group, although the simple surpass them in means for digits forwards and backwards. The paranoid and simple are very close and not far below the catatonic, the

hebephrenic and unclassified definitely inferior with the hebephrenic outstandingly low. Where many differences were found for any item it was usually the case that the others surpassed the hebephrenics.

In comparisons made between the various types and other psychoses outstanding findings are: little difference between paranoid dementia praecox and paranoid condition, although the latter are closer to the normal; a striking similarity between the hebephrenic and paretic groups. sufficient to make the distinction of the psychometric picture all but impossible; and another striking similarity between the catatonic and manic-depressive, which makes these psychometrically indistinguishable.

MANIC-DEPRESSIVE

As was stated earlier, this is a heterogeneous group, comprising all types, but all of them examined during comparatively quiescent periods. The group is so like the normal in all test results—distribution, means, and items– as to be indistinguishable in psychometric performance.

PSYCHOPATHIC PERSONALITIES

These two groups are extraordinarily close in age, education and mean test results, and approximate the normal, although they fall somewhat below.

PARANOID CONDITION

This group falls quite close to the normal and psychometrically may be considered as essentially the same.

PSYCHONEUROSIS

The mean test results for this group are very close to the normal, but the group tended to be somewhat higher than the normal on some individual items. We did not find our neurotics more variable than normals. In comparison with psychopathic personality without psychosis, the psychoneurotic are of higher level.

WITHOUT PSYCHOSIS

Analysis of this group was of particular interest because of the frequent appearances in the literature of similar groups which have been used as normal controls. This group had the fourth largest number of significant differences from the normal in the item analysis. Mean test results were all markedly lower, the differences being significant for vocabulary and digits forwards and possibly so for Stanford-Binet score. The mental level of this group is 152 months. The item analysis showed the disturbance to be chiefly apparent in memory items, including vocabulary and to a much smaller degree in thinking items.

APPENDIX I

TABLE 29

AGE DATA FOR ALL GROUPS

		N	Range	Mean	S.D.
Normal	R	70	15–59	36.1 ± 1.5	12.8 ± 1.1
General Paresis	R	35	27–68	40.6 ± 1.3	7.6 ± 0.9
	n-R	24	26–53	38.7 ± 1.4	6.9 ± 1.0
Chronic Alcoholism with Psychosis	R	30	28–63	44.1 ± 1.8	9.8 ± 1.3
	n-R	12	31–65	46.0 ± 3.3	10.8 ± 2.3
Chronic Alcoholism without Psychosis	R	12	30–58	41.8 ± 2.5	8.4 ± 1.8
	n-R*	2	37–46	41.5	
Acute Alcoholic Psychosis	R	17	18–50	35.9 ± 2.0	8.1 ± 1.4
	n-R*	6	28–59	39.7	
Feeblemindedness with Psychosis	R	60	12–52	32.2 ± 1.3	10.2 ± 0.9
	n-R	25	15–47	28.2 ± 1.9	9.1 ± 1.3
Feeblemindedness without Psychosis	R	27	13–50	25.7 ± 1.8	9.4 ± 1.3
	n-R*	10	11–57	26.2	
Paranoid Dementia Praecox	R	58	18–54	34.1 ± 1.1	8.5 ± 0.8
	n-R	31	19–49	34.6 ± 1.5	8.0 ± 1.0
Hebephrenic Dementia Praecox	R	32	15–59	29.1 ± 1.6	8.6 ± 1.1
	n-R	29	16–51	29.2 ± 1.5	8.1 ± 1.1
Catatonic Dementia Praecox	R	30	17–40	24.8 ± 1.1	6.2 ± 0.8
	n-R	28	18–37	21.6 ± 0.8	4.1 ± 0.6
Simple Dementia Praecox	R	22	20–58	30.5 ± 2.2	9.9 ± 1.5
	n-R*	7	27–34	30.3	
Unclassified Dementia Praecox	R	38	14–65	28.1 ± 1.6	9.7 ± 1.1
	n-R	25	16–40	26.1 ± 1.2	5.9 ± 0.8
Manic-Depressive	R	19	18–62	35.0 ± 3.0	12.7 ± 2.1
	n-R	18	18–56	32.3 ± 2.7	10.9 ± 1.9
Psychopathic Pers. with Psychosis	R	22	11–45	23.9 ± 1.8	8.1 ± 1.3
	n-R	14	12–62	29.5 ± 3.4	12.3 ± 2.4
Psychopathic Pers. without Psychosis	R	21	14–68	25.1 ± 3.0	13.2 ± 2.1
	n-R*	4	25–36	26.5	
Paranoid Condition	R	22	23–53	39.8 ± 2.1	9.5 ± 1.5
	n-R*	9	26–57	40.4	
Psychoneurosis	R	36	14–62	27.8 ± 1.8	10.4 ± 1.2
	n-R*	12	16–45	27.4 ± 2.8	9.3 ± 2.0
Without Psychosis	R	72	10–48	26.1 ± 1.1	9.3 ± 0.8
	n-R	18	12–51	27.7 ± 2.8	11.6 ± 2.0

*Too small for inclusion in discussion.

TABLE 30
EDUCATION DATA FOR ALL GROUPS

		N	Range	Mean	S.D.
Normal	R	61	0 16	8.1±0.1	3.0±0.2
General Paresis	R	33	2 16	8.6±0.5	2.8±0.4
	n-R	22	0 17	8.2±1.0	4.4±0.7
Chronic Alcoholism with Psychosis	R	29	2 11	6.9±0.6	3.3±0.4
	n-R*	12	0 12	5.8	3.6
Chronic Alcoholism without Psychosis	R	11	3–19	7.2±1.3	4.3±0.9
	n-R*	2	0–8	4.0	
Acute Alcoholic Psychosis	R	11	6-16	8.7±0.7	2.7±0.5
	n-R*	5	4-12	7.0	
Feeblemindedness with Psychosis	R	55	0 12	4.8±0.4	2.7±0.3
	n-R	21	0 8	4.6±0.5	2.6±0.4
Feeblemindedness without Psychosis	R	25	3 8	5.8±0.3	1.4±0.2
	n-R*	10	0 7	3.0	2.4
Paranoid Dementia Praecox	R	55	0-17	8.5±0.5	3.5±0.3
	n-R	31	2-16	8.8±0.6	3.1±0.4
Hebephrenic Dementia Praecox	R	31	2-14	8.5±0.5	2.7±0.4
	n-R	29	4 12	8.2±0.5	2.6±0.3
Catatonic Dementia Praecox	R	30	2-16	9.9±0.6	3.0±0.4
	n-R	28	4-16	9.6±0.6	3.2±0.4
Simple Dementia Praecox	R	22	2–16	9.0±0.8	3.5±0.5
	n-R*	7	2-12	7.7	
Unclassified Dementia Praecox	R	37	0–16	8.4±0.6	3.3±0.4
	n-R	21	3–13	8.3±0.4	2.1±0.3
Manic Depressive	R	19	5 15	8.8±0.7	2.9±0.5
	n-R	17	5 16	9.9±0.7	2.9±0.5
Psychopathic Pers. with Psychosis	R	22	2-15	7.6±0.6	2.8±0.4
	n-R	14	5-13	8.7±0.7	2.6±0.5
Psychopathic Pers. without Psychosis	R	21	1–12	7.8±0.7	3.2±0.5
	n-R*	4	5-10	7.8	
Paranoid Condition	R	22	4–14	9.1±0.7	3.1±0.5
	n-R*	9	5–12	8.2	
Psychoneurosis	R	36	0–19	9.4±0.6	3.5±0.4
	n-R*	11	7–12	9.9	1.7
Without Psychosis	R	72	1–18	7.7±0.3	2.9±0.2
	n-R	18	2–11	6.2±0.6	2.5±0.4

*Too small for inclusion in discussion.

TABLE 31

OCCUPATION DATA FOR ALL GROUPS (TAUSSIG CLASSES)

		I	II	III	IV	V
Normal		2% (1)	28% (15)	28% (15)	31% (18)	8% (4)
General Paresis	R	3% (1)	31% (11)	16% (5)	31% (11)	13% (4)
	n-R	13% (3)	17% (4)	22% (5)	39% (9)	8% (2)
Chronic Alcoholism with Psychosis	R	3% (1)	13% (4)	37% (11)	30% (9)	17% (5)
	n-R					
Chronic Alcoholism without Psychosis	R	8% (1)	8% (1)	25% (3)	50% (6)	8% (1)
	n-R					
Acute Alcoholic Psychosis	R	6% (1)	18% (3)	35% (6)	23% (4)	18% (3)
	n-R					
Feeblemindedness with Psychosis	R	0% (0)	7% (3)	11% (5)	58% (26)	21% (11)
	n-R	0% (0)	7% (1)	0% (0)	61% (9)	29% (4)
Feeblemindedness without Psychosis	R	0% (0)	0% (0)	11% (3)	53% (11)	33% (7)
	n-R					
Paranoid Dementia Praecox	R	2% (1)	18% (9)	29% (15)	29% (15)	22% (11)
	n-R	7% (2)	21% (6)	31% (9)	31% (10)	7% (2)
Hebephrenic Dementia Praecox	R	0% (0)	20% (5)	32% (8)	28% (7)	20% (5)
	n-R	0% (0)	8% (2)	32% (8)	28% (7)	32% (8)
Catatonic Dementia Praecox	R	5% (1)	32% (7)	18% (4)	11% (9)	5% (1)
	n-R	0% (0)	32% (6)	26% (5)	21% (4)	21% (4)
Simple Dementia Praecox	R	0% (0)	27% (4)	13% (2)	27% (4)	33% (5)
	n-R					
Unclassified Dementia Praecox	R	0% (0)	34% (11)	13% (4)	28% (9)	25% (8)
	n-R	0% (0)	22% (4)	22% (4)	28% (5)	28% (5)
Manic-Depressive	R	6% (1)	25% (4)	31% (5)	38% (6)	0% (0)
	n-R	0% (0)	47% (8)	0% (0)	11% (7)	12% (2)
Psychopathic Pers. with Psychosis	R	0% (0)	27% (3)	18% (2)	55% (6)	0% (0)
	n-R	9% (1)	9% (1)	18% (2)	61% (7)	0% (0)
Psychopathic Pers. without Psychosis	R	0% (0)	17% (2)	17% (2)	25% (3)	11% (5)
	n-R					
Paranoid Condition	R	10% (2)	25% (5)	15% (3)	30% (6)	20% (4)
	n-R					
Psychoneurosis	R	16% (4)	8% (2)	28% (7)	40% (10)	8% (2)
	n-R					
Without Psychosis	R	2% (1)	12% (7)	22% (13)	41% (24)	24% (14)
	n-R	0% (0)	13% (2)	20% (3)	20% (3)	47% (7)

TABLE 32

DATA FOR STANFORD BINET SCORE IN MONTHS FOR ALL GROUPS

		N	Range	Mean	S.D.
Normal	R	65	96-231	163.6±3.1	25.0±2.2
General Paresis	R	35	68-206	132.1±5.4	31.2±3.8
	n-R	21	62-160	113.1±5.1	24.3±3.6
Chronic Alcoholism with Psychosis	R	30	87-195	145.9±5.4	29.2±3.8
	n-R*	12	82-153	110.8	21.8
Chronic Alcoholism without Psychosis	R	12	123-211	155.3±6.9	24.0±4.9
	n-R*	2	108-146	127.0	
Acute Alcoholic Psychosis	R	17	96-222	154.2±7.9	31.5±5.6
	n-R*	6	109-143	131.8	
Feeblemindedness with Psychosis	R	60	38-116	93.8±2.9	22.2±2.0
	n-R	25	40-130	92.8±3.7	18.0±2.6
Feeblemindedness without Psychosis	R	27	61-139	104.1±3.6	18.3±2.5
	n-R*	10	42-140	91.6	33.1
Paranoid Dementia Praecox	R	58	82-231	154.8±4.4	33.5±3.1
	n-R	31	80-190	135.7±5.9	32.0±4.1
Hebephrenic Dementia Praecox	R	32	72-197	129.4±5.4	30.0±3.8
	n-R	28	36-173	105.1±6.9	36.0±4.9
Catatonic Dementia Praecox	R	31	96-217	164.8±5.3	29.1±3.8
	n-R	28	56-202	140.1±6.9	35.7±4.9
Simple Dementia Praecox	R	22	80-228	155.5±7.1	32.4±5.0
	n-R*	7	72-128	101.7	
Unclassified Dementia Praecox	R	38	61-215	144.0±5.9	35.6±4.1
	n-R	25	78-190	131.6±7.0	34.4±5.0
Manic-Depressive	R	19	114-222	166.4±7.5	32.0±5.3
	n-R	18	84-203	144.6±8.3	34.0±5.8
Psychopathic Pers. with Psychosis	R	22	109-234	156.1±6.4	29.4±4.5
	n-R	11	101-193	138.8±6.3	23.4±4.4
Psychopathic Pers. without Psychosis	R	21	84-223	156.4±6.9	30.8±4.9
	n-R*	4	127-169	143.8	
Paranoid Condition	R	22	122-211	164.7±5.5	25.1±3.9
	n-R*	9	80-203	143.8	
Psychoneurosis	R	36	106-234	169.1±4.8	28.5±3.4
	n-R*	12	108-196	153.1	33.5
Without Psychosis	R	72	80-229	152.7±4.0	33.4±2.8
	n-R	18	84-189	133.7±7.3	30.0±5.1

*Too small for inclusion in discussion.

Table 33

Data for Vocabulary Scores for All Groups

		N	Range	Mean	S.D.
Normal	R	69	25–86	54.5±1.9	15.6±1.3
General Paresis	R	34	14–80	47.4±2.7	15.3±1.9
	n-R	21	10–69	39.1±3.6	16.3±2.6
Chronic Alcoholism with Psychosis	R	29	20–79	49.9±3.0	15.9±2.1
	n-R*	12	10–60	34.8	
Chronic Alcoholism without Psychosis	R	12	38–88	54.5±3.9	13.7±2.8
	n-R*	2	28–48	38.0	
Acute Alcoholic Psychosis	R	15	29–83	54.9±2.5	9.4±1.8
	n-R*	6	14–50	39.7	
Feeblemindedness with Psychosis	R	57	0–65	22.7±1.9	14.1±1.3
	n-R	22	0–36	22.1±1.8	8.4±1.3
Feeblemindedness without Psychosis	R	26	2–46	26.0±2.5	12.6±1.8
	n-R*	10	0–57	20.7	
Paranoid Dementia Praecox	R	55	0–90	56.1±2.2	16.0±1.5
	n-R	31	10–76	48.7±3.5	19.3±2.5
Hebephrenic Dementia Praecox	R	31	10–78	42.0±3.8	20.7±2.7
	n-R	29	0–70	31.2±4.2	22.2±3.0
Catatonic Dementia Praecox	R	31	10–80	57.0±3.2	17.0±2.3
	n-R	28	10–82	49.5±3.7	19.0±2.6
Simple Dementia Praecox	R	22	25–80	53.1±3.3	15.3±2.4
	n-R*	7	10–41	29.0	
Unclassified Dementia Praecox	R	37	14–87	50.1±2.9	17.5±2.1
	n-R	21	0–80	43.3±4.3	20.6±3.0
Manic-Depressive	R	18	36–81	58.7±3.3	13.6±2.3
	n-R	18	10–92	56.7±4.8	19.7±3.4
Psychopathic Pers. with Psychosis	R	21	30–80	48.9±3.3	14.8±2.3
	n-R	14	32–70	45.9±3.7	13.5±2.6
Psychopathic Pers. without Psychosis	R	21	13–84	49.2±4.1	18.2±2.9
	n-R*	4	20–51	40.0	
Paranoid Condition	R	22	26–82	58.8±3.2	14.7±2.3
	n-R*	9	24–81	52.1	
Psychoneurosis	R	34	30–92	53.7±2.7	15.2±1.9
	n-R*	12	24–80	54.8	
Without Psychosis	R	71	14–88	48.0±1.8	14.9±1.3
	n-R	17	10–66	36.0±4.4	17.6±3.1

*Too small for inclusion in discussion.

TABLE 34

DATA FOR DIGITS FORWARDS FOR ALL GROUPS

		N	Range	Mean	S.D.
Normal	R	65	4-8	6.69±0.12	1.02±0.09
General Paresis	R	34	3-8	5.53±0.20	1.14±0.14
	n-R	24	4-8	5.29±0.19	0.89±0.13
Chronic Alcoholism with Psychosis	R	29	0-8	5.83±0.28	1.48±0.20
	n-R*	12	4-7	4.8	
Chronic Alcoholism without Psychosis	R	12	5-8	6.25±0.31	1.09±0.22
	n-R*	2	4-7	5.5	
Acute Alcoholic Psychosis	R	17	3-8	6.00±0.32	1.28±0.23
	n-R*	6	5-7	5.67	
Feeblemindedness with Psychosis	R	60	0-7	4.52±0.18	1.40±0.13
	n-R	25	3-6	4.56±0.15	1.75±0.11
Feeblemindedness without Psychosis	R	26	0-6	4.81±0.26	1.30±0.18
	n-R*	9	0-7	4.3	
Paranoid Dementia Praecox	R	57	4-8	6.11±0.15	1.10±0.10
	n-R	31	4-9	5.81±0.22	1.18±0.15
Hebephrenic Dementia Praecox	R	32	4-8	5.53±0.14	0.79±0.10
	n-R	28	0-7	4.93±0.26	1.36±0.19
Catatonic Dementia Praecox	R	31	4-8	6.52±0.19	1.03±0.13
	n-R	28	4-8	5.93±0.17	0.88±0.12
Simple Dementia Praecox	R	22	5-9	6.59±0.25	1.15±0.18
	n-R*	7	4-7	5.60	
Unclassified Dementia Praecox	R	38	4-8	5.95±0.20	1.21±0.14
	n-R	21	3-8	5.79±0.23	1.08±0.16
Manic-Depressive	R	19	4-8	6.74±0.27	1.16±0.19
	n-R	17	4-7	5.65±0.30	1.21±0.21
Psychopathic Pers. with Psychosis	R	21	5-8	6.19±0.19	0.85±0.13
	n-R	14	4-8	6.07±0.30	0.01±0.18
Psychopathic Pers. without Psychosis	R	21	4-8	6.29±0.26	1.16±0.18
	n-R*	4	5-6	5.5	
Paranoid Condition	R	22	4-8	5.95±0.22	1.02±0.16
	n-R*	9	4-8	5.78	
Psychoneurosis	R	35	4-8	6.54±0.16	0.92±0.11
	n-R*	12	3-8	5.67	
Without Psychosis	R	72	3-8	6.01±0.14	1.17±0.10
	n-R	17	4-8	6.12±0.26	1.02±0.18

*Too small for inclusion in discussion.

TABLE 35

DATA FOR DIGITS BACKWARDS FOR ALL GROUPS

		N	Range	Mean	S.D.
Normal	R	65	3 7	1.87 ± 0.11	1.16 ± 0.10
General Paresis	R	25	0-7	3.69 ± 0.29	1.71 ± 0.21
	n-R	23	0 6	3.01 ± 0.34	1.63 ± 0.21
Chronic Alcoholism with Psychosis	R	30	0 7	4.07 ± 0.30	1.62 ± 0.21
	n-R*	12	0 5	2.08	
Chronic Alcoholism without Psychosis	R	12	4 6	4.50 ± 0.23	0.76 ± 0.16
	n-R*	2		4.00	
Acute Alcoholic Psychosis	R	17	0-7	1.17 ± 0.13	1.71 ± 0.30
	n-R*	6	3 4	3.83	
Feeblemindedness with Psychosis	R	60	0 5	1.72 ± 0.23	1.76 ± 0.17
	n-R	21	0 5	2.29 ± 0.29	1.41 ± 0.21
Feeblemindedness without Psychosis	R	27	0 5	2.67 ± 0.33	1.67 ± 0.21
	n-R*	9	0 5	1.67	
Paranoid Dementia Praecox	R	58	0 7	4.52 ± 0.16	1.23 ± 0.11
	n-R	29	0-7	4.21 ± 0.26	1.40 ± 0.19
Hebephrenic Dementia Praecox	R	29	3-7	4.31 ± 0.21	1.07 ± 0.15
	n-R	27	0 6	3.26 ± 0.21	1.23 ± 0.17
Catatonic Dementia Praecox	R	30	3 7	4.77 ± 0.28	1.45 ± 0.20
	n-R	28	3 7	4.50 ± 0.29	1.54 ± 0.20
Simple Dementia Praecox	R	21	3 8	5.21 ± 0.27	1.17 ± 0.19
	n-R*	5	3	3.00	
Unclassified Dementia Praecox	R	37	0 7	1.11 ± 0.27	1.60 ± 0.19
	n-R	23	0 8	4.18 ± 0.31	1.63 ± 0.24
Manic-Depressive	R	19	3-7	4.89 ± 0.21	1.00 ± 0.17
	n-R	16	3 6	4.06 ± 0.36	1.31 ± 0.24
Psychopathic Pers. with Psychosis	R	22	3 7	4.77 ± 0.24	1.07 ± 0.17
	n-R	14	3-7	4.57 ± 0.30	1.18 ± 0.21
Psychopathic Pers. without Psychosis	R	21	3-7	4.71 ± 0.27	1.18 ± 0.19
	n-R*	4	2–6	4.25	
Paranoid Condition	R	22	3-7	4.86 ± 0.22	1.00 ± 0.15
	n-R*	8	0–5	4.38	
Psychoneurosis	R	36	0–7	5.17 ± 0.27	1.55 ± 0.19
	n-R*	12	3–7	4.58	
Without Psychosis	R	72	0–7	4.51 ± 0.18	1.45 ± 0.13
	n-R	18	0–6	4.00 ± 0.29	1.20 ± 0.21

*Too small for inclusion in discussion.

APPENDIX II

The Stanford-Binet in Clinical Practice

Of what value is the Stanford-Binet in testing in the state hospital situation? As we have seen, as a research instrument it leaves much to be desired. For research with disordered persons, an omnibus test is of considerably less value than a battery of tests of definable functions. Some of the types included in the Stanford appear to be of very great value, indeed, but except for the vocabulary, the scales are much too short. In addition, it is still true that adequate adult standardization is not available and that the expressing of adult scores in MA terms is highly undesirable.

The new Stanford has not, to any extent, overcome these handicaps. In spite of all of these justifiable and important criticisms, and the limitations thereby imposed on the Stanford, it still remains one of the most useful techniques as yet available to the clinician*. In the hands of a skilled examiner, the test situation can yield a good deal more than the MA. Careful analysis of item passes and failures, of vocabulary and MA relationships, and so on, well repays the additional time, and, properly interpreted, the results may be of considerable value to the psychiatrist and others working with the patient. It is necessary, however, to emphasize repeatedly the extensive training required for such use of this, or any test.

APPENDIX III

Prospectus

Surely the outstanding conclusion to be drawn from all of the foregoing is the considerable value, as a research and a diagnostic tool, which a battery of well-chosen adequately standardized tests would have for work with abnormal adults. Enormous as such a project seems at first thought, the difficulties to be encountered in the light of our present knowledge would be chiefly financial and administrative. The value of small samples, when properly selected, is becoming increasingly apparent in many fields, and the problems involved in population selection are now fairly well understood, vide the Gallup polls.

For many reasons, the Gallup technique alone would not serve, chief

*The Bellevue Intelligence test, designed primarily for adults and standardized on a reasonably well
elected sample is headed in the right direction but has some defects in organization. So far as research
oes—or even analysis in the individual case—it seems unfortunate that separate norms have not been
given for digits forwards and digits backwards instead of having them lumped into one test, for they
apparently do not test the same thing, or that items for more than 9 digits forwards and 8 backwards
have not been included. Presumably, Wechsler converts his scores into IQ's because of the familiarity
of psychiatrists and others with the term (as computed by him it is essentially a variant of a sigma
score). This seems not entirely desirable since psychiatrists themselves are recognizing the weaknesses
of the IQ. The test, however, appears to have been well devised for adults and we believe should prove
highly acceptable for research as well as in clinical practice.

among them being the reluctance of many people to take psychological examinations. Once the characters of the groups needed have been specified, the individual subjects themselves can, in our opinion, be most easily obtained on the surgical wards of general and private hospitals, as was done by Weisenburg, Roe, and McBride (1936). It is true that for some of the tests very nearly adequate norms could be constructed from reports now in the literature, but this would not permit of computing intercorrelations between functions, one of the important problems to be solved.

Given, however, the possibility of getting an adequate standardization group at each desired age level, what tests would this and other research suggest?

These may be considered under several headings:

1. Attention and Memory Tests. The two types are here discussed together because it is extremely important for the understanding of psychosis to be able to distinguish between span of attention and span of memory. Further, the memory tests must be so arranged as to permit discrimination between failures due to inability to fixate and failures due to inability to retain. The material utilized should include among other types verbal and non-verbal (including designs) and meaningful and non-meaningful. The Worcester-Wells Memory Test, as well as memory items in other tests should prove a useful starting point, but in this group the need for considerable preliminary research is indicated.

2. Vocabulary Tests. The Stanford-Binet vocabulary is well known and agreement on scoring is fairly well developed, so that objections on other grounds seem to be overweighted. A multiple choice test, such as the Thorndike Word Knowledge, meets many of the objections to which the Stanford vocabulary is open, but a paper and pencil test is generally undesirable for psychotics.

3. Comprehension Test. The comprehension test in the Bellevue scale would probably serve very well, but some non-verbal item, such as an adult version of the Healy PC II, could well be included.

4. Tests of Conceptual Thinking. In this group should be included such tests as are exemplified in the following Binet items: absurdities, induction, problem questions, president and king, and fables, and such a test as that devised by Bolles (1937). These should, where possible, be of both verbal and non-verbal sorts. The two absurdities tests used by Weisenburg, Roe, and McBride (1936) each containing 11 items, were considered unsatisfactory by them because of the uneveness in increment of difficulty, but by combin-

ing the two, and perhaps adding a few items at either end of the scale, a satisfactory test could be devised. The analogies tests from the same study should prove fruitful, and arithmetical progressions should be considered. Several of the Bellevue Intelligence Tests are probably of the same basic type.

The form in which adult norms should be expressed is of considerable importance. The score should be of a sort which automatically locates the individual with respect to the distribution of his own group, whatever that may be taken to be. (Definition of the groups should follow some further consideration of the factor of age than the simple convenience of splitting by decades and it is preferable to construct norms for the two sexes separately, at least in preliminary studies.) A standard frequency distribution method recently devised by Simpson and Roe (1942) offers a simple and comprehensible method which fulfils the requirements expressed above and has many advantages over the various versions of sigma scores and MA equivalents now in use. This method is based on the standard range concepts developed by Simpson (1941), and uses an abscissal decile technique. Calculation is reduced to a minimum through the use of tables and standard charts.

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